Itek 9555-80-939
Project: 9555
DRL No.: T-1418
Line Item: 19
DRD No.: MA-129TA

Itek

FINAL REPORT
19 DECEMBER 1980

ORBITER CAMERA PAYLOAD SYSTEM

Contract No. NAS 9-15671

Itek Optical Systems
A Division of Itek Corporation

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas
77058

**ORIGINAL PAGE IS
OF POOR QUALITY**

3/13/81

Reply To Attn of ED8-81L-55

TO : Distribution

FROM: ED82/OCPS Project Manager

SUBJ: Errata to Contract NAS9-15671, Contractor Final Report, Orbiter Camera Payload System, Itek Document 9555-80-939, dated 12/19/80

The NAS9-15671 Contractor's Final Report was transmitted to you under letter ED8-81L-29, on February 5, 1981. Due to an editorial oversight, two formulae had not been composed completely by the typist and were not caught by the proofreaders prior to printing.

Please make the following substitutions to your copy of the report:

1. Section II, page 2.

"Terrain heighting error = σ_h"

$$\sigma_h = \frac{[(1/MR)^2 + 2\tau^2 + 2D_F^2 + 2D_L^2]^{1/2} H}{f\ (B:H)}$$

2. Section II, page 4.

"Relative terrain point-positioning error = σ_p"

$$\sigma_p = \pm \frac{[(1/2R)^2 + \tau^2 + D_F^2 + D_L^2 + 2(f\sigma_h \tan \alpha/H)^2]^{1/2} H}{f}$$

B. H. Mollberg

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Please make corrections prior to release. I missed these errors during my review.

Bernie Mollberg
3/13/81

cc:
BC24/L. Bloom

Itek 9555-80-939
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FINAL REPORT
19 DECEMBER 1980

ORBITER CAMERA PAYLOAD SYSTEM

Contract No. NAS 9-15671

Director
Aircraft Systems

Itek Optical Systems
A Division of Itek Corporation

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NONE

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SECTION 5 - ABSTRACT

Contract NAS9-15671 has supplied certain components for an Orbiting Camera Payload System (OCPS). These include the Large Format Camera (LFC), a Gas Supply Assembly (GSA) and ground test, handling, and calibration hardware.

The LFC, the prime component of the OCPS to date, is a high resolution Large Format photogrammetric camera for use in the cargo bay of the Space Transport System. It is also adaptable to use on an RB-57 aircraft or on a free-flyer satellite.

Carrying 4000 feet of film, the LFC is usable over the visible to near IR, at V/h rates of from 11 to 41 milliradians per second, overlap of 10, 60, 70 or 80 percent and exposure times of from 4 to 32 milliseconds. With a 12 inch focal length it produces a 9 by 18 inch format (long dimension in line of flight) with full format low contrast resolution of 88 lines per millimeter (AWAR), full format distortion of less than 14 microns and a complement of 45 Reseau marks and 12 fiducial marks. Weight of the OCPS as supplied, fully loaded is 944 pounds and power dissipation is 273 watts average when in operate, 95 watts in standby.

The LFC contains an internal exposure sensor, or will respond to external command. It is able to photograph starfields for in-flight calibration upon command.

Designed to satisfy many needs, the LFC is ready for integration with a flight vehicle.

SECTION 6 - TABLE OF CONTENTS

NOTE: Sections are per MA-129TA Outline

SECTION 6 - TABLE OF CONTENTS CONT.

SECTION 6 - TABLE OF CONTENTS CONT.

LIST OF TABLES AND FIGURES

SECTION 7 - DEFINITIONS

ADP	- Acceptance Data Package
ATV	- Acceptance Thermal/Vacuum (Test)
AWAR	- Area Weighted Average Resolution
CARR	- Contractor Acceptance Readiness Review
DMR	- Discrepant Material Report
EVA	- Extra Vehicular Activity
FCD	- Film Change Detector
FMC	- Forward Motion Compensation
FR	- Failure Report
GFE	- Government Furnished Equipment
GFP	- Government Furnished Property
GPCA	- Gas Pressure Control Assembly
GSA	- Gas Supply Assembly, Including Hose
GSE	- Ground Support Equipment
LFC	- Large Format Camera (Lens Cone, Magazine Electronics Box, and Environmental Enclosure)
LOF	- Line of Flight
l/mm	- Line (Pairs) per Millimeter
MTBF	- Mean Time Between Failures
OCPS	- Orbiter Camera Payload System
PPA	- Principal Point of Autocollimation
PPS	- Principal Point of Symmetry
RID	- Review Item Disposition
SRQ&M	- Safety, Reliability, Quality and Maintainance
STS	- Shuttle Orbiter Space Transportation System
T&C (Console)	- Test and Checkout Console, Including Cables
TM	- Telemetry Data
V/h	- Angular Rate of Change of Target, Radians/Sec.
EIFOV	- Effective Instantaneous Field of View
MSS	- Multi Spectral Scanner

SECTION 8 - SUMMARY

See Abstract, Section 5

SECTION 9 - RESULTS

The OCPS project, as defined by NASA Contract NAS9-15671, has been successfully completed with no deviations or waivers and no unresolved problems. Key results are summarized in this section with reference to more detail, if available, in other sections of this report. For detailed information and backup details, refer to the Acceptance Data Package.

Resolution:

Full format AWAR on 3414, lens only, is 88 LPM, low contrast. Full system resolution at V/h = .026 radians per second, exposure time = .006 seconds, low contrast and at the +9 degree field position is 84 LPM. For more data, see Section 12, Table 2.

Distortion:

Full format distortion is ±14 microns. For more data, see Section 12, Tech. Spec. review, paragraph 3.2.1.1.

Format:

The format is 9" x 18", long dimension in line of flight. See Section 12, Fig. 1.

Calibration Data:

Calibration data including platen calibration (reseau), PPA, PPS and Fiducial Calibration and TM calibrations is filed under volume IV of the ADP.

Weight:

Weight of a fully loaded OCPS is 943 pounds. See Section 12, Table 3 for a breakdown.

Outline Dimensions:

Detailed in ICD-SLD-047-000001-802

Center of Gravities:

Detailed in ICD-SLD-047-000001-802

Moments of Inertia:

Detailed in ICD-SLD-047-000001-802

Power Dissipation:

Will be mission dependant, but for a worst case mission will be 273 watts average and 613 watts, peak (50 millisecond duration per frame). See ICD-SLD-047-000001-803 for more data.

Gas Consumption:

For a seven day mission using up all 4000 feet of film, 8.6 pounds of GN_2.

SECTION 10 - CONCLUSIONS

The OCPS components delivered under Contract NAS9-15671 have been built without deviation or waiver to the Technical Specification (Exhibit II of the Contract) and are ready for integration into the flight vehicle.

With certain modifications, the OCPS may be interfaced with an RB-57 or a Free Flier Satellite.

SECTION 11 - OCPS APPLICATIONS - TECHNICAL DATA

As a space-borne sensing and imaging instrument, the LFC has unique characteristics relative to other past, present, and planned NASA earth observation systems. These characteristics are identified as follows:

Stereoscopic Imaging with variable base/height ratios.

The wide field of view provided by the LFC lens, combined with the large film format, permits vertical (map-like) photography with a variety of stereo overlap conditions providing stereo-models with base/height ratios of from 0.3 to 1.2.

Geometric Precision and metric calibration

Optical distortions are minimized and calibrated and relate to a precisely calibrated focal length. Format fiducial reference and focal plane reseau references geometrically relate the film to the optical image and allow corrections for film deformations. The camera environmental control system is designed to maintain the calibrated geometric characteristics.

This combination of geometric knowledge and control permits the determination of the projective relationship between photo coordinates and terrain features.

Spatial Resolution with high definition aerial films.

Depending on the orbital altitude and choice of film, the LFC offers the potential of meeting most currently stated requirements for terrain spatial information from a space-borne sensor. The most frequently stated need of 10 meter resolution can be provided on black and white film on an area weighted average resolution (AWAR) basis from a nominal Orbiter altitude of 278 kilometers. Figure 1.

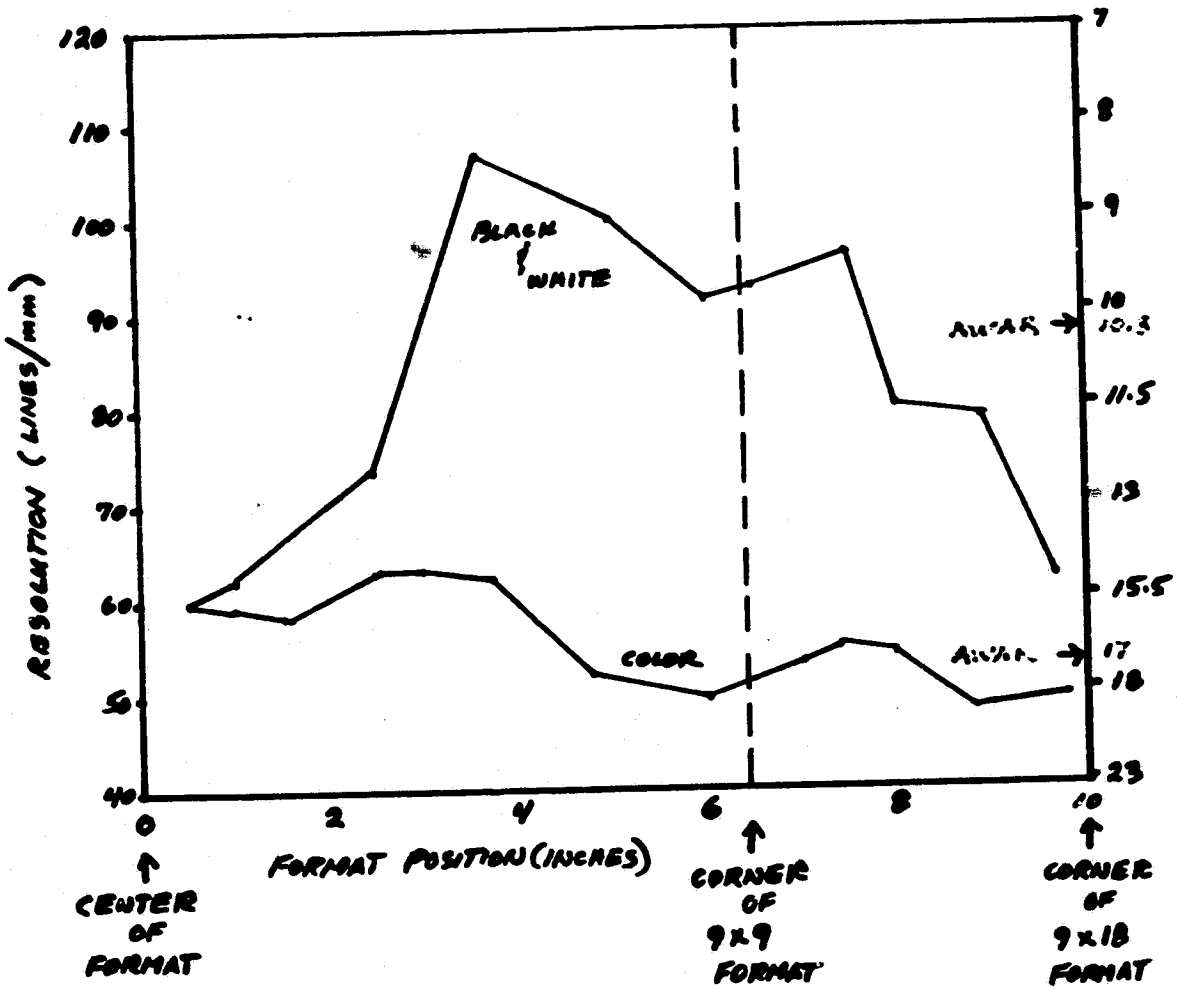
Final LFC Characteristics vs. Selected Applications

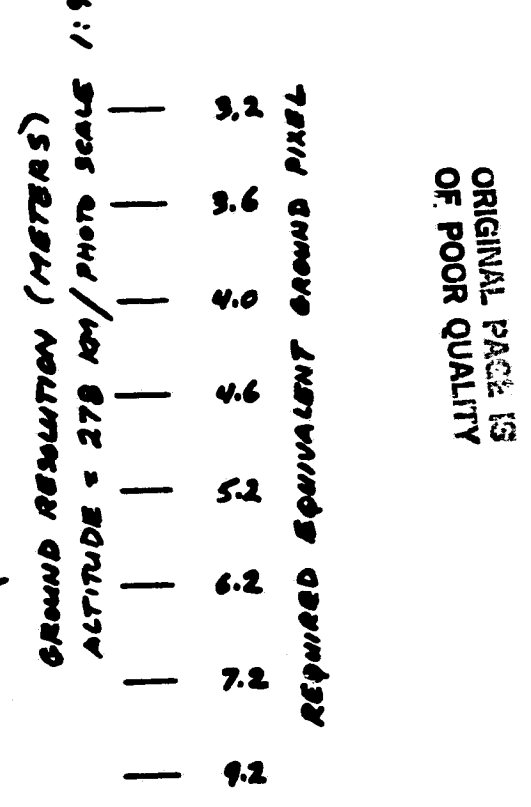
The three above identified characteristics combined with the less unique, but equally important features of large area coverage and signature recognition (through the use of color films) offers potential for a great many operational applications. With high resolution stereo and calibrated geometry the most obvious is TOPOGRAPHIC MAPPING to specified map scales and related accuracies. The topographic "theme" is, of course, a primary input to applications in geology, hydrology, land-use, geography and engineering. Of equal importance is PHOTOGEOLOGIC MAPPING AND PHOTOGEOLOGIC INTERPRETATION, where three dimensional dips, faults, stratigraphic breaks and fold axes may be assembled in the form of a map for understanding geomorphic and structural relationships.

LARGE FORMAT CAMERA (LFC)

LOW CONTRAST RESOLUTION SUMMARY
OF SELECTED CANDIDATE FLIGHT FILMS
(TARGET CONTRAST = 2:1)

(VALUES ARE POST VIBRATION
AT ENVIR. TEMP AND PRESSURE)





NOTE:
GROUND FOOTPRINT OF LFC
AT 278 KM. ALT.
ALONG TRACK:
417 KM (225 N.MI.)
ACROSS TRACK
208 KM (112 N.MI.)

FIGURE 1

Height and Position Determination

To assess the potential of LFC imaging for TOPOGRAPHIC and GEOLOGIC MAPPING based on the relevant final camera characteristics we can develop the following:

Terrain heighting error = σ_h

$$\sigma_h = \pm \frac{(1/MR)^2 + 2\tau^2 + 2D_F^2 + 2D_L^2)^{1/2} H}{f\,(B:H)}$$

where

σ_h = Relative point heighting error (in meters)

H = Altitude (in meters)

f = Lens focal length (in millimeters)

B:H = Base/height ratio

M = Parallax clearance factor

R = System resolution (in lines per millimeter)

τ = Measuring instrument accuracy (in millimeters)

D_F = Uncompensated film distortion (in millimeters)

D_L = Uncompensated lens distortion (in millimeters)

To compute the relative (within stereo model) heighting error using the altitude (H) consistent with the ground resolution values in Figure 1, we use the following values:

H = 278,000 meters (150 nautical miles) - typical

f = 305.767 millimeters (actual CFL)

B:H = 0.90 (for 40-percent forward overlap model) - typical

M = 6.0 (normal range is 2.5 to 10)

R = 77 lines per millimeter (actual adjusted for duplication photos) *

τ = 0.002 millimeter (normal range is 0.001 to 0.006 millimeters)

D_F = 0.005 millimeter (normal range is 0.002 to 0.007 millimters)

D_L = 0.0038 millimeter (actual)

* Resolution value based on:

- 88.1 l/mm AWAR/low contrast/post-vibrational environment.
- 2.9 percent FMC factor at 26 mrad/sec (278 kilometers)
- 10 percent loss from duplication of ON to user's duplicate (DP)
- final 77.1 l/mm

σ_h from 278 kilometer altitude therefore equals ± 9.6 meters which, with conventional photogrammetric mapmaking practice would permit a 25-30 meter contour map meeting U.S. National mapping accuracy Class A standards. An orbital altitude of 222 kilometers (120 n.mi.) would allow a 20 meter contour interval which is consistent with a 1:50,000 scale topographic map which is a basic international economic planning document.

As a guide to relative heighting potential using different altitudes and different base/height ratios, the following chart is provided.

Item	Camera frame numbers			
	1 and 2	1 and 3	1 and 4	1 and 5
Forward overlap (percent)	80	60	40	20
Base to height ratio	0.3	0.6	0.9	1.2
Relative point-heighting error (meters)				
222 km (120 n.mi.) altitude	± 23.2	± 11.6	± 7.7	± 5.8
278 km (150 n.mi.) altitude	± 29.0	± 14.5	± 9.6	± 7.2
417 km (225 n.mi.) altitude	± 43.5	± 21.7	±14.5	±10.9

LFC Relative Height Predictions
Using Final Camera Values

Relative terrain point-positioning error = σ_p

$$\sigma_p = \pm \frac{(1/2\ R)^2 + \tau^2\ D_F + D_L + 2(f\sigma_h \tan \alpha/H)^2\ ^{1/2} H}{f}$$

where (in addition to factors previously defined) tan α = terrain slope at measured points (in degrees). If the average slope (α) for rolling terrain is 34 degrees, the relative point-positioning error (σ_p) is about ± 12 meters. For a 1:50,000 scale map, 90 percent of the (absolute) horizontal position of points shall not be in error by more than ± 25 meters, so that fitting coordinates of points determined from LFC photos to surveyed ground control has the full potential of meeting map requirements. Again the point-positioning error can vary as a function of altitude, base-height ratio, and terrain slope while maintaining the constant camera/photo values.

Item	Camera frame numbers			
	1 and 2	1 and 3	1 and 4	1 and 5
Parameter				
Forward overlap (percent)	80	60	40	20
Base to height ratio	0.3	0.6	0.9	1.2
Relative point-positioning error (meters)				
34° Slope 222 km altitude	± 22.6	± 12.7	± 9.8	± 8.6
34° Slope 278 km altitude	± 28.2	± 15.9	±12.2	±10.7
34° Slope 417 km altitude	± 42.3	± 23.7	±18.4	±16.1

LFC Relative Point-Positioning Potential

APPLICATIONS OF LFC SPATIAL RESOLUTION

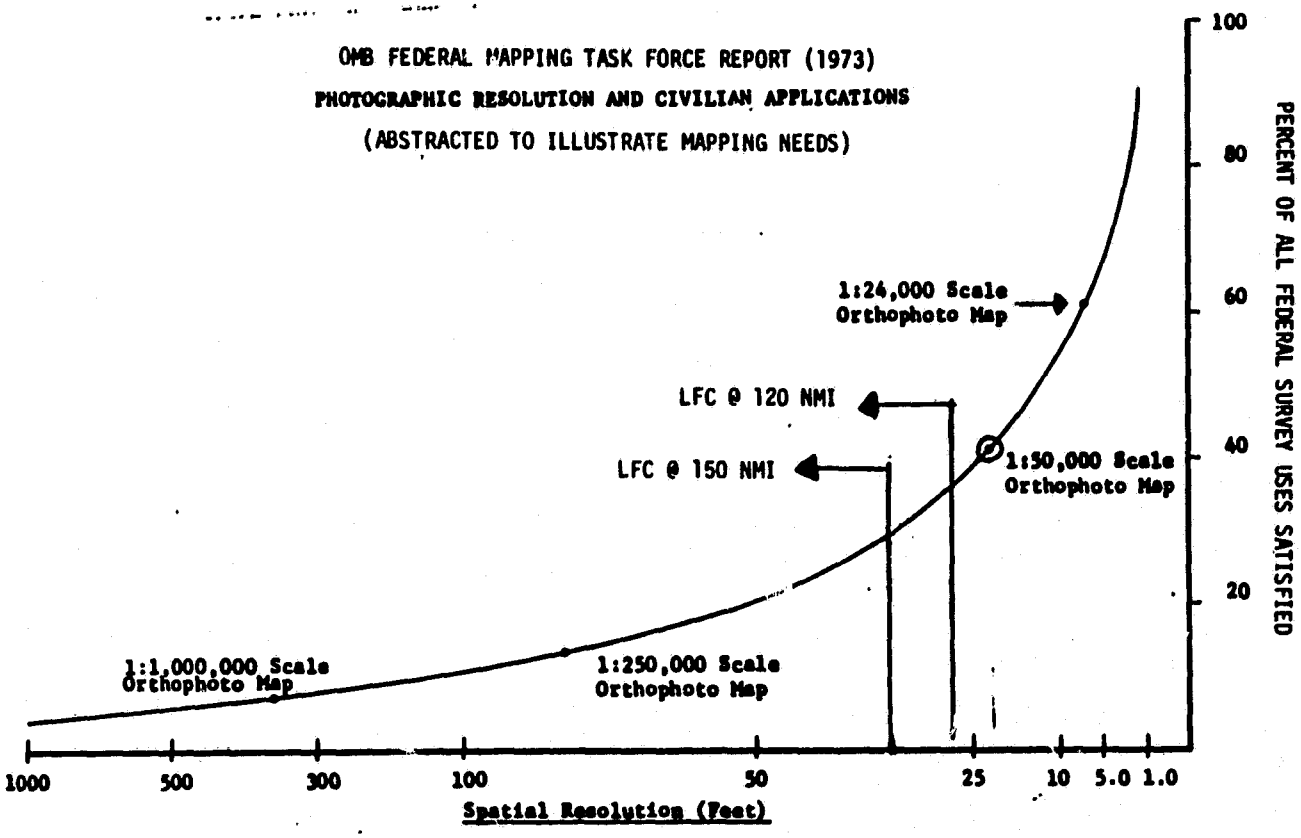
In this era of airborne and satellite remote sensing with both photo-optical and electro-optical sensors, the question of spatial resolution requirements and sensor capability becomes somewhat confused by how the questions are asked.

TOPOGRAPHIC MAPPING

Because of the long tradition in the compilation of topographic maps from aerial surveys (i.e., photo-optical) the term "photographic resolution" is often used to define the requirement for the level of detail needed to interpret or reproduce objects of importance to users of the map. Unlike quantitative requirements such as height and position errors, spatial resolution for completion of the map product is often dependent upon the area or country photographed.

The following graph, from an OMB Task Force Report of 1973, applies to spatial resolution needs of 39 Federal agencies engaged in topographic and thematic mapping and particularly identifies resolution required for map content of national mapping scales. The graph, as abstracted from the Report, shows that the LFC with AWAR's of approximately 10 meters and 8 meters from altitudes of 150 and 120nmi respectively, meets almost all of the spatial resolution requirements of Federal maps at scales of 1:50,000 and smaller.

On a global basis, the 1:50,000 series is considered the standard economic planning map scale for developing areas and, according to a 1976 U.N. study, less than 25% of the earths land mass has adequately current coverage at that scale.



RESOURCE SURVEYS

Because of the LANDSAT influence on the communications and terminology of resource remote sensing, statements of applications requirements sometimes do not differentiate between photographic lines per millimeter (and ground resolved distance) and electro-optical detectors (and EIFOV). Such is the case with the following chart of requirements compiled by representatives of geologic industries. Nevertheless the nominal spatial resolution of 10 meters meets almost 100% of the oil, gas, and minerals resolution needs and two-thirds of the geologic environmental and engineering needs.

Summary of the frequency of Geosat capabilities recommended for sensing various geological parameters.[a]

Geosat Capabilities[b]	Frequency of recommendation: Totals[c]	% [d]	Oil and Gas: No.	% [d]	Minerals: No.	% [d]	Engineering and Environment: No.	% [d]
Number of capabilities mentioned	133	100.0%	20	100%	71	100%	42	100%
Structure recognition	55	41.4	13	65.0	28	39.4	14	33.3
Signature recognition	81	60.9	10	50.0	49	69.0	22	52.4
Minimum resolution:								
50-meter	3	2.2	--	--	3	4.2	--	--
30-meter	33	24.8	7	35.0	22	31.0	4	9.5
< 10-meter	17	12.8	--	--	3	4.2	14	33.3
Magnetics	6	4.5	4	20.0	2	2.8	--	--
Gravity	4	3.0	3	15.0	1	1.4	--	--
Radar	76	57.1	17	85.0	24	33.8	35	83.3
Thermal IR	78	58.6	12	60.0	43	60.6	23	54.8
Passive microwave	8	6.0	--	--	--	--	8	19.0
Laser fluoresence	20	15.0	4	20.0	11	15.5	5	11.9
Thermal inertia	24	18.0	--	--	21	29.6	3	7.1
Fraunhofer discrimination	9	6.8	--	--	9	12.7	--	--
Lageos	1	0.8	1	5.0	--	--	--	--
Spectral bands (μm):	The original table continued with spectral band preferences.							

a. Because these data were originated by the separate working groups at the Geosat Workshop, there may be some inconsistencies in their derivation. However, the frequencies of recommendations for Geosat capabilities are representative of their relative significance as appraised by the Geosat Workshop.

b. Remote sensing capabilities recommended by the Geosat Workshop for a geologically dedicated satellite in space.

c. These are the sums of Oil and Gas, Minerals, and Engineering and Environment columns.

d. These are percentages of the total number of capabilities or spectral bands in each column (the first entry).

The following 4 tables are from the Dept. of Commerce report, "Planning for a Civil Operational Remote Sensing Satellite System", June 20, 1980. The original tables included "mission" oriented parameters such as frequency, area, etc. which have not been included in this discussion of a sensor.

They illustrate that a 10-meter GRD system meets 100% of the "Minimum Acceptable Value" for spatial resolution requirements, 100% of the "Optimum Value" for State, Local, and Private applications, and 62% of the "Optimum Value" for Federal applications. The tables also illustrate the requirement for the LFC feature of Stereo Coverage.

Relative to Spectral Bands the LFC film options include the visible and near I.R., however, not in digital form as raw data nor as narrowly selective as the MSS.

APPLICATIONS RELATED TO GROWTH POTENTIAL OF OCPS

An OCPS "growth potential" list includes both augmentation and duplication of LFC features which would provide more complete information for planned applications and add more users.

Duplication of LFC

A productive technique of modern aerial surveys is twin camera operation where high spatial resolution and spectral signature enhancement is achieved by synchronous photography with two identical cameras with different films. This is currently worldwide practice from high altitude aircraft.

High-Resolution Augmentation

All stated resolution requirements, down to the level of 3-5 meters GRD, can be satisfied by augmenting the metric and strong stereo features of LFC with existing NASA high resolution, wide-coverage cameras such as the Apollo Panoramic systems. This, of course, would be done on an area - need basis.

Attitude Sensing and/or Recording Devices

The relative accuracies of the LFC can be extended to be "absolute" accuracies by providing simultaneous sensing and recording of "line-of-sight". This can be accomplished by either film recording of starfields or by electro-optical stellar sensing. Ground control requirements would be minimized.

High resolution augmentation and attitude sensing could provide the potential for larger scale topographic and thematic mapping close to the needs for the domestic U.S. map series at a scale of 1:25,000.

TABLE III-1
SUMMARY OF POSSIBLE REQUIREMENTS FOR LAND REMOTE SENSING (All Domestic Users) (Based on Available Data as of April 1, 1980)

Performance Parameter	PROGRAMMATIC CATEGORY GROUPS: Renewable Resources	Non Renewable Resources	Planning/Environmental Management
Spatial Resolution (Meters)	Range 2-80 m; 10-30 m Most Useful 2-30 m meets 90% of Requirements[1/]	Range 3-100 m; 30-80 m Most Useful 3-30 m meets 30% of Requirements	10-80 m, 10-30 m Most Useful
	10-30 m meets 81% of Requirements	10-30 m meets 28% of Requirements	10-30 m meets 60% of Requirements
	15-30 m meets 80% of Requirements[2/]	15-30 m meets 26% of Requirements[2/]	15-30 m meets 50% of Requirements[2/]
	30-80 m meets 10% of Requirements	30-80 m meets 70% of Requirements	30-80 m meets 40% of Requirements
Spectral Bands	MSS/TM Type Plus Microwave	MSS/TM Type Plus Microwave	MSS/TM Type
Stereo Coverage	Needed for 20% of the Requirements	Needed for 36% of the Requirements	Needed for 18% of the Requirements

TABLE III-2
SUMMARY OF POSSIBLE FEDERAL REQUIREMENTS FOR LAND REMOTE SENSING

Performance Parameters	Percent of Requirements Satisfied by Specified System Parameter: Optimum Value	Minimum Acceptable Value
Spatial Resolution (Meters)	2-3 m – 37% 10 m – 33% 30 m – 28% 80 m – 2%	10 m – 25% 30 m – 20% 80 m – 55%
Spectral Bands	TM Type – 100%[1/]	MSS-Type – 100%
Stereo Coverage	Needed for 20% of Requirements	Needed for 20% or Requirements

TABLE III-3
SUMMARY OF POSSIBLE STATE/LOCAL GOVERNMENT
REQUIREMENTS FOR LAND REMOTE SENSING
(Based on Available Data as of April 1, 1980)

	Percent of Requirements Specifying Value	
Performance Parameters	Optimum Value	Minimum Acceptable Value
Spatial Resolution (Meters)	10-30 m – 42% 30-50 m – 50% 80 m – 8%	30 m – 6% 80 m – 94%
Spectral Bands	TM TYPE – 100%[1/]	MSS Type – 100%
Stereo Coverage	Needed By 13%	None Specified

TABLE III-4
SUMMARY OF POSSIBLE U.S. PRIVATE REQUIREMENTS
(Based on Available Data as of April 1, 1980)

	Domestic U.S. Coverage		Foreign Coverage	
Performance Parameter	Optimum Values	Minimum Acceptable	Optimum Values	Minimum Acceptable
Spatial Resolution (Meters)	10 m – 64% 30 m – 36%	30 m – 71% 80 m – 29%	10 m – 71% 30 m – 29%	30 m – 80% 80 m – 14%
Spectral Bands	TM TYPE – [illegible][1/] Radar – 14%	MSS Type – 100%	TM Type – 100%[1/]	MSS Type – 100%
Stereo Coverage	Needed for 50% of Requirements		Needed for 50% of Requirements	

Dual-Mode Focal Plane

Film and Electro-Optical focal planes can be combined to achieve the following features:

1. Extend mission life beyond film capacity.

2. Lower resolution E-O data where needs are met or where political sensitivity requires it.

3. Near real-time response.

4. Narrow band spectral selectivity.

SECTION 12 - MAIN BODY

OBJECTIVE

The objective of this contract has been to satisfy the requirements outlined in Exhibit B of the contract (The Technical Specification) for the OCPS. These requirements describe a high resolution, Large Format photogrammetric camera system for space useage. In this section of the final report, a paragraph by paragraph review of the Technical Specification is presented with brief discussion to demonstrate compliance. Study programs and other efforts which contributed to the final product are reviewed. Items of major interest, technical problems and failures since the start of acceptance testing are highlighted.

TECHNICAL SPECIFICATION REVIEW

Scope

The OCPS has been designed to be hard mounted to a Flight Support Structure (not included as a part of this contract) mounted within the cargo bay of the STS. The OCPS components have been designed for multiple useages, with up to 50 missions comtemplated.

Applicable Documents - Used as Required

Requirements

General

The OCPS is designed for useage in the STS payload bay for visible and near Infra-Red data collection over the altitude range of 185 to 600 KM.

OCPS Components

The deliverables are listed as Table 1.

LFC

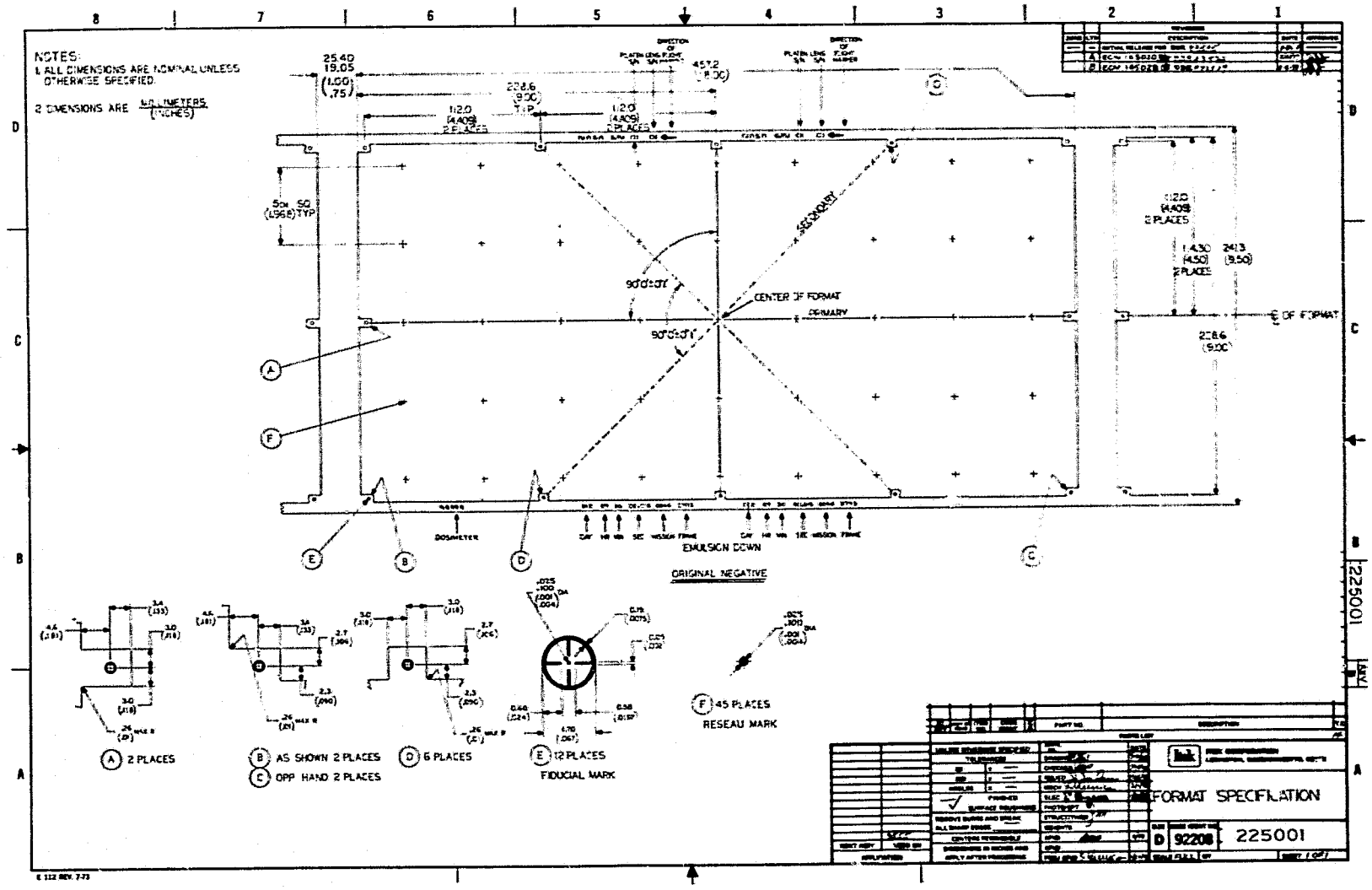
Capabilities

Format:

The LFC format is defined in Drawing 225001 (Itek) reproduced here as Fig. 1 which describes size, margin, reseaux, fiducials, auxilliary data and key dimensions. The relationship of the fiducials intersections, the Principal Point of Autocollimation, the Principal Point of Symmetry and the Center of Format has been measured and found to be within a 30 micron diameter circle. Test data is summarized in Volume IV of the ADP.

TABLE 1 - DELIVERABLES

	QUANTITY
Flight Orbiter Camera Payload System:	
(Large Format Camera)	
Lens Cone Assembly (225130G1)	1
Film Magazine Assembly (225038G1)	1
Electronics Assembly (225085G1)	1
Environmental Enclosure (225294G1)	1
High Pressure Gas Supply System (225206P1)	1
Film Spools (4000 ft.) (225140G1) (225140G2)	20
Ground Support and Checkout Equipment:	
Electrical Test & Checkout Unit (225858G1)	1
T&C Cable Set (225829G1 thru G5)	1
Extender Card Set (225592G1)	1
Lifting Fixture Set (198623G1)	1
Lens Cone Shipping Container (225899G1)	1
Film Magazine Shipping Container (225899G2)	1
Lens Cone Cover, Front (225802G1)	1
Lens Cone Cover, Rear (225827G1)	1
Film Magazine Cover (225853G1)	1
Film Magazine Assy. Dolly (225800G1)	1
Lens Cone Assy. Dolly (198650G1)	1
Film Thickness Adjustment Plate (225812G1)	1
Focal Plane Calibration Fixture (225808G1,2,3)	1
Interconnecting Cabling (225883G1 thru G5)	1
Spool Handling Sling (198634G1)	1



Film Load:

The LFC will accommodate on standard 9 1/2" film spools up to 2000 feet of 3414, or, on special spools (provided), 4000 feet. All standard aerial film emulsions on 2.5 or 4.0 mil bases may be accommodated.

Operating Modes:

The LFC may be operated in Standby (heaters on), Test (five frame burst) Operate (sequential exposures), or Calibrate (stellar). Overlaps of 10%, 60%, 70% or 80% may be commanded.

Power Useage:

LFC power requirements are tabulated in ICD SLD-047-000001-803 (NASA-JSC) and are 273 watts maximum average, and 613 watts maximum peak when operating, and 95 watts in standby.

Resolution:

Measured resolution data is tabulated in Table 2. Detailed data is included in the ADP, Vol. IV.

Distortion:

Symmetrical radial distortion has been measured to be $\pm$ 2 microns over the central 9" x 9" area and $\pm$ 14 microns over the entire format.

Light Tightness:

Baffles in the film path allow a loaded Magazine to be assembled onto the Lens Cone under daylight conditions with the fogging of less than 1 meter of film.

Weight:

The OCPS weights are as listed in Table 3.

Lens Cone Assembly

The Lens Cone Assembly contains the structural member which forms both the mating surface for Magazine and Environmental Enclosure attachment, eventual attachment of the LFC to a flight support structure, and supports the connectors for interface to the LFC Electronics Box. The Magazine attachment scheme allows for replacement in space by EVA.

Optical Considerations:

The measured focal length is 305.767mm. Aperture by design is 49.2mm minimum. Spectral transmission data (measured) is tabulated in Tables A & B. There are two intra-lens mounted filters, selectable in flight. Filter number one is a GG435 Minus Haze, and filter number two is an OG515 Minus Blue. Transmission uniformity across the field is $\pm$ 7%.

TABLE 2 - RESOLUTION DATA (LINE PAIRS PER MILLIMETER)

Film Type	Lens Resolution: Low Contrast, Full Format AWAR		Lens Resolution: High Contrast, Central 9 x 9 AWAR		Lens Resolution: High Contrast, 9 x 18 Minimum Corner Resolution		System Resolution (Moving Targets): Average, Low Contrast, 6 M's. Exposure								
							.011 r/s			.026 r/s			.041 r/s		
3414	88	125	91	138	61	103	67	88	68	66	84	67	65	84	66
3412	67	NR	69	NR	49	NR									
SO-131	39	NR	41	NR	34	NR									
SO-242	54	NR	58	NR	48	NR									
							-34^{o}	$+9^{o}$	$+34^{o}$	-34^{o}	$+9^{o}$	-34^{o}	-34^{o}	$+9^{o}$	-34^{o}
										Field Positions					

NR = Not Reported (Not Required)

TABLE 3 - OCPS WEIGHTS

Integrated Lens Cone/Magazine (With 4000 ft. of 3414)/
Environmental Enclosure: 827.4 lbs.

Gas Supply Assembly with Full 2400 PSIG (GN_2)
Charge: 47 lbs. 15 oz.

Camera Electronics Assembly: 68.4 lbs.

TABLE A

AVERAGE SPECTRAL TRANSMISSIONS

SPECTRAL REGION	AVERAGE	T/no.
415-720nm	19.3%	13.7
505-720nm	19.5%	13.6
515-880nm	19.5%	13.6

TABLE B

FULL FIELD TRANSMISSION OVER 580 to 720nm

DIRECTION OF FILM TRAVEL ↓

ANGLE	t	RI	T/No.
-35^{o}	19.75%	1.013	13.5
-25	19.31%	.99	13.7
-15	18.27%	.937	14.0
0^{o}	19.5%	1.00	13.6
+15	18.92%	.97	13.8
+25	19.36%	.993	13.6
+35	20.42%	1.047	13.3

Exposure Control:

The LFC utilizes a rotary shutter with a calculated efficiency of 73%. The commandable range of exposures is .004 to .032 seconds. An internal sensor will, upon command, provide the exposure command. A flight selectable bias of zero or + 1/2 stop and a film type selector (flight selectable) for 3412, SO-131 and SO242, or 3414 are provided. A center of exposure pulse, accurate to within 225 microseconds, drives the fiducials.

Thermal Control:

The lens is maintained at a setpoint of 19.8°C, ±.25C for STS operational environments.

Magazine

The magazine stores and translates film in a light tight environment. When demated from the Lens Cone, baffles prevent the fogging of all but 1 meter of film.

Capacities:

Are per Table 4.

Film Thickness:

The magazine will accommodate emulsions on .0025 and .004 inch bases.

Platen Considerations:

Film is vacuum clamped to a platen for exposure. The platen has a measured flatness to within ±10 μm. Forty five reseaux built into the platen expose a reseau pattern while the film is clamped. A platen calibration (reseau) (by serial number) has been included as a part of the ADP, Vol. IV. The platen utilizes FMC to translate the film in the LOF direction during exposure. Measured data demonstrates this correction to be within approximately ±2% of ideal (reader error limited). The platen is maintained at 19.6°C ±0.4°C.

Pneumatic Considerations:

In order to develop a vacuum clamp in space, the internal camera pressure is maintained at 2.0 + 0.2 PSIG. Measured data suggests that a seven day mission on which the entire film load is used up will require 8.6 pounds of gas (the GSA capacity is 10.0 pounds).

Mixed Loads:

Mixed loads of film on a common base thickness are allowable. A Film Change Detector, which is triggered by the special splice described in (Itek) Document ES225088, provides an indication of change on the TM line.

TABLE 4 - MAGAZINE CAPACITIES

KODAK TYPE	ON STANDARD SPOOLS	ON SPECIAL LFC SPOOLS
3414	Up to 2000'	Up to 4107
3412	Up to 2000'	Up to 4107'
SO-242	Up to 1800'	Up to 3313'
SO-131	Up to 1800'	Up to 3262'

Camera Electronics

The bulk of the LFC electronics are housed in the Camera Electronics Assembly. This package, measuring 2' x 2' x 1', may be located up to 25 feet (of cable run) from the Lens Cone/Magazine Assemblies. Flight Cables for use in interfacing the Electronics Assembly to the Lens Cone are not provided since the desired configuration is mission dependant and as yet undetermined. The STS/LFC electrical interface is accomplished at the Electronics Assembly via four connectors. Refer to the LFC ICD's for details.

Fusing:

The 28V lines from the STS are fused within the LFC before distribution to circuitry. A 25 ampere fuse is used for heater power while two paralleled 25 ampere fuses are used for operate power.

Environmental Enclosure

The environmental enclosure, consisting of a fiberglass shroud, a thermal door over the entrance pupil, insulating blankets and heater elements fits over the Lens Cone Assembly. The door opens for any mode other than Standby and may be commanded open in Standby by a Thermal Door override command.

Command, Signal and Data Functions

These considerations are discussed in detail in the Functional and Electrical ICD's, SLD-47-000001-801 and SLD-47-000001-803 (NASA-JSC). A listing by name only of commands is presented in Table 5, while Flag Data, TM Data and Ground Test Points are presented in Tables 6, 7 and 8 respectively.

Ground Support Equipment

The deliverables are listed in Table 1.

Protective Covers:

Are supplied for all critical applications.

Shipping Containers:

Are provided. Those not listed as deliverables are wooden crates to be built upon packing for shipment. All are passive except for the Lens Cone Assembly shipping container which requires 115 volts at 10 amps for heater power when the exterior environment is below $-7^{o}C$ ($20^{o}F$) for extended periods (see ICD-SLD-47-000001-901-NASA-JSC).

Calibration Fixtures:

Two are supplied. One, the Focal Plane Calibration Fixture is used in measurement of Lens distortion. The other, the Film Thickness Adjustment Fixture is used to set LFC focus.

TABLE 5 - COMMANDS

Power: ON/OFF
Mode Select: STDBY, TEST, OP, CAL
Thermal Door Override: Open, Normal
Overlap: 10%, 60%, 70%, 80%
Exposure Bias: 0, +1/2 stop, -1/2 stop
Capping Shutter Select: Open, normal
V/h command: Analog
Exposure Command: Analog
Filter Select: Pos. 1, Pos. 2
Film Type
Fiducial Inhibit: Ground test only
Reseau Inhibit: Ground test only
FMC Inhibit: Ground test only
Time Code: IRIG B, NASA MOD.

TABLE 6 - FLAG DATA

Temperature Fault
Go/NO-GO
BUSY
Low Film
Thermal Door Status
Center Exposure Pulse

TABLE 7 - TM DATA

CHANNEL NUMBER	
1	Supply Side Dancer Position
2	Supply Spool Velocity
3	Takeup Side Dancer Position
4	Takeup Spool Velocity
5	FMC Rate
6	Framing Roller Rate
7	Platen Pressure
8	LFC Internal Pressure
9	Low Pressure Supply Temperature
10	Rotary Shutter Velocity
11	Thermal Door Temperature
12	Gas Supply Assy. Temperature
13	Camera Lens Temperature
14	Camera Support Structure Temperature
15	Platen Temperature
16	Magazine Base Temperature
17	Magazine Cover Temperature
18	Temperature Spare
19	Environmental Enclosure Temperature - Zone 1
20	Environmental Enclosure Temperature - Zone 2
21	Electronics Assy. Temperature
22	Supply Spool Radius
23	Spare
24	Spare
25	Frame Count - MSB
26	Frame Count - LSB
27	Exposure Sensor Output
28	Gas Supply Assy. Pressure
29	Spare
30	Film Change Detector
31	Capping Shutter Position Bit 1
32	Capping Shutter Position Bit 2
33	Spare
34	Spare
35	Filter Position No. 1
36	Filter Position No. 2
37	Spare
38	Spare

TABLE 8 - GROUND TEST POINTS

Supply Spool Motor Current
Takeup Spool Motor Current
Filter Changer Motor Current
FMC Motor Current
Thermal Door Motor Current
+15V Monitor
-15V Monitor
+5V Monitor
Framing Roller Motor Current
Rotary Shutter Motor Current
Capping Shutter Motor Current
Takeup Spool Radius
Rotary Shutter Brake Status
End of Exposure Pulse
Supply Brake Status
Framing Brake Status

Checkout Equipment:

A T&C Console is provided which supplies all power and commands to the OCPS and monitors all Flag, TM and ground test point outputs. It is described in ICD-SLD-47-000001-901 (NASA-JSC). It is a 2 bay console designed for laboratory useage only, requires 115V AC 60Hz and 208V AC, 60Hz, both single phase. It contains all necessary monitoring equipment for OCPS checkout.

Dollies:

Two are provided. One is used for the Magazine only (film loading, checkout, etc.) while the other is used for Lens Cone Assembly or Lens Cone/Magazine integrated operation.

Slings:

Two types of slings are provided. One is an H structure with four cables to be used in lifting the Magazine, the Lens Cone or the integrated Lens Cone/Magazine. The second is a belt designed for use in supporting a spool of film (70 lbs.) during loading or unloading operations. These are described in the ICD-SLD-47-000001-901 document.

Extender Cards:

A set of six is provided. These are all of an identical design.

Spares

There are no spares delivered under this contract. A provisioning list has been submitted as DRL line item 7.

Operability

The OCPS has been designed to survive the handling, storage and transportation, ascent, deorbit and post landing environments described in ICD-SLD-47-000001-804, to operate in a laboratory environment and to operate within specification in the Earth Orbit environment, also described in the -804 ICD.

Interface

Requirements are defined by the documents listed in Table 9.

Design and Construction (Flight)

Is detailed in the OCPS drawing package, 225000 (Itek) and those drawings subsequently referenced under that number. The OCPS has been designed and built to perform its mission of high resolution, photogrammetic quality photography in an orbital environment, and to survive the environments encountered in getting there and back. Design lifetime is 50 missions. EMI considerations are outlined under ICD-SLD-47-000001-804 (NASA-JSC).

TABLE 9 - INTERFACE DOCUMENTS

NASA ICD-2-19001	Shuttle System/Cargo Standard Interface Specification
ESA REF. NO. SLP 2104	ESA Spacelab Payload Accommodation Handbook
SLD-47-000001-801	Functional (OCPS)
SLD-47-000001-802	Mechanical (OCPS)
SLD-47-000001-803	Electrical (OCPS)
SLD-47-000001-804	Environmental (OCPS)
SLD-47-000001-808	Gas Supply Assembly (OCPS)
SLD-47-000001-901	BTE & Ground Handling Equipment (OCPS)
SLD-47-000001-902	Launch and Recovery Facilities (OCPS)

Design and Construction (GSE)

Is detailed in the various drawing packages (See Table 1) SW-E-0002B has been used as a guide. The T&C, Cables, Dollies and calibration devices are designed for use only in a laboratory environment. The shipping containers are designed for truck, rail or air transport in a weather protected environment.

QUALITY ASSURANCE

NHB 5300.4 (1D-1) has been used as a guide. Overall S, R, Q & M (Safety, Reliability, Quality and Maintainability) considerations were per Itek Document 9555-78-009, Rev. A (OCPS SRQ&M Plan). Specifics relating to inspection were per Itek Document 9555-78-008, Rev. A, OCPS Inspection System Plan.

TEST REQUIREMENTS

Itek Document 9555-78-007, Rev. A, OCPS Acceptance Test Plan describes the test program. The Certification Matrix, submitted with the ADP addresses the Technical Specification on a line by line basis and outlines the means by which compliance is verified.

PREPARATION FOR DELIVERY

Instructions for breaking down and packing are contained in the LFC Operation and Maintainance Manual.

Historical Sketch

As interest developed in the acquisition of a high resolution wide angle cartographic camera for orbital applications, Itek was awarded Contract NAS9-15490 to study the application of a Large Format Camera to the Orbiter program as a part of the OCPS. This study contract developed preliminary interface control documents, discussed mission parameters and considered the application of the LFC to a free flier satellite and to the RB-57.

A proposal effort was begun at Itek in response to RFP-NAS-9-BC241-A83-8-11P which led to the awarding of Contract NAS9-15671 on July 21, 1978 for the production of OCPS components, principally the LFC.

The LFC design was based on Itek's Metritek 30 Cartographic Lens, the result of 10 years developmental efforts and characterized by significant advances in lens design, shutter efficiency and reliability, and environmental control for geometric stability.

As the LFC program progressed, several areas of significant interest developed in the design. To provide a cost effective and stable lens housing, Mehanite was chosen as a material. In order that program scheduling constraints be met, accelerated aging techniques involving elevated temperatures were employed. Machining of the lens cell casting to the required accuracies was contracted out to Contraves Goerz. Fiducial projectors physically connected to the

Lens Cone which were both adjustable and stable to the required accuracies were developed. Likewise a rear projection reseau system was developed into the platen with the assistance of Duane Brown of Geodetic Services, Inc. The platen is a 9 by 18 inch vacuum clamped platen flat to within ±10 microns and having a built in reseau system of 45 projectors on 5 centimeter centers.

With an eye towards the eventual useage on a free flyer, the LFC was designed to be a smooth running system providing a minimum torque disturbance to its mount. Continuously rotating supply and takeup spools coupled with film storage "dancers" to decouple framing motion from the spools were key factors in a quiet camera design.

To further limit disturbances in the lens area during exposure, and to provide high efficiency, a continuously rotating three bladed shutter combined with a capping shutter having a specially profiled acceleration curve were employed.

The internal pressurization of the LFC provided a benign environment for motors, bearings, etc., as well as providing a necessary contributor to the vacuum clamping operation. Control of internal pressure and vacuum, and eventually the supply of high pressure input gas as well was subcontracted out to Carleton Control Corporation, a firm involved in several related tasks for the Space Shuttle program at that time.

A self contained exposure sensor was developed for the LFC. As the LFC is carried forward by the Orbiter, the exposure sensor examines a 1.8^{0} spot at nadir and searches for the lowest brightness level over a period inversely proportional to altitude (0.6/V/h). After the data collection period, the result is used to control exposure over the next period, while new data is being sampled. By using the lowest brightness level to control exposure, the effects of clouds, specular reflection from water, and snow cover are removed from the exposure decision.

The LFC program proceeded through the PDR and CDR stages with little difficulty. As assembly began in earnest, procurement difficulties in the areas of semiconductor devices, connectors, certain other piece parts and the Carleton Gas Pressure Control Assembly began to be felt. Workarounds, including a set of test boards built with commercial parts (where available), were devised to keep the project on schedule.

During assembly, integration, debug and test, the normal amount of difficulties for a first unit production were encountered. Considering that, except for a prototype lens and a breadboard platen, this camera was developed without benefit of extensive breadboarding, the difficulties were few indeed. The total impact, schedulewise, of the problems encountered was to slip the contract end date from June 4, 1980 to December 31, 1980. During that period of 30 weeks, the program was inactive for 7 weeks due to test facility scheduling.

A brief synopsis of the more significant problems follows:

Lens Area

1. Production of the Aspheric Element (Lens Element #3) was complicated by difficulties with an in-house aspheric measurement machine. These problems were resolved by measuring performance at a higher level of assembly.

2. Testing of the completed lens revealed that Element #4 had been made from the wrong glass type. Itek feels that the initial delivery of the glass from the vendor was in error. Index of refraction is not routinely checked, as vendor data is relied on.

3. PFA testing was plagued by repeatability problems at first. These were discovered to be temperature driven and procedural corrections were implemented.

Procurement Area

1. Procurement of high reliability EEE parts forced the program to develop workarounds including test boards of commercial quality and lower reliability parallel procurement for substitution on an as needed basis. These workarounds allowed the program to improve on portions of the schedule but added to the cost. Longest lead components were integrated circuits and connectors at up to 18 months.

2. Procurement of the GPCA from Carleton Controls was substantially late. This delayed the discovery of serious design flaws within the GPCA which contributed greatly to the overall OCPS program slippage. Certain workarounds were attempted but were of limited usefulness during the Acceptance Test phase, because verification of a working GPCA on an LFC is an essential part of acceptance. These problems were resolved by returning the unit (several times) to the vendor for redesign/repair and suffering from the schedule and cost impact to the program.

3. Interconnecting Cables were procurred from a cable house and had severe workmanship problems in the area of contact crimping. Throughout the program, intermittents and opens confused general debugging activities and accounted for perhaps 3 weeks of schedule slippage, total. This problem was resolved by rework as needed both at the original vendor's and in-house.

4. Personal Radiation Dosimeter (GFE)

   An additional problem area was the Personal Radiation Dosimeter (PRD). In the original contract, the GFE PRD was to interface to the LFC to provide an accumulated dosage figure in the auxiliary data block. A fair amount of effort had been expended towards this effort when the PRD was deleted by the government.

5. Functional Anomalies during the 1st ATV Test

The first ATV test suffered from five major functional anomalies, all of which have been corrected. They were:

Defocus:

The mating of the magazine assembly to the Lens Cone Assembly did not provide the expected focal plane positioning for the platen due to a problem involving O-Ring compression. This problem was resolved by resetting the lens to magazine mating surfaces. Refer to FR2826.

FMC Mismatch:

The response of the platen to a V/h command did not produce the desired result. A mismatch test revealed the platen to be 9% fast. This was corrected by changing the amount of tachometer feedback. Refer to FR2826.

Standby Failure:

The LFC did not return to a proper standby mode throughout the test. This led to a variety of "ripple effects" such as poor start-ups and shut-downs and high power dissipation. This was traced to a workmanship problem in which a burr on a transistor mount shorted the transistor out. This was repaired by replacing all stressed parts and repairing the burr. Refer to F.R.3699.

Aux. Data Anomalies:

The auxiliary data display showed erratic output. This was traced to a design problem involving bandwidth limiting of a line driver. The condition was corrected by increasing the line driver bandwidth. Refer to FR2828.

GPCA Failure:

The GPCA failed and would not regulate in vacuum conditions. To complete the series of tests, it was bypassed through the use of a commercial regulator. Repair was accomplished later by return to the vendor. The GPCA pressure transducers also failed to work in a vacuum. See FR3697.

Problem Areas During the Final ATV Test

Review of the final ATV test revealed several areas of generally minor concern (Reference the "Acceptance Review Report" DRL line #17). A brief summary of the more significant of these follows:

1. Heater Power Disable

A review of the operation of this feature led to a discussion of its value. NASA requested data to be used to delete the "heater power disable" and such was supplied in the answer to CARR RID E1. NASA will hold this as an option.

2. Startup Anomaly (Ref. CARR RID E-4).

   A feature designed to allow a return to standby in the event of broken or jammed film (an unlikely event) produces undesirable startup difficulties under certain conditions. Although these conditions are rare, they were observed twice during the final ATV test. Itek has suggested the feature be removed and has supplied NASA with the details of accomplishing this in the form of an unincorporated change notice (see DRL line #17). NASA intends to incorporate the change.

3. GN_2 Consumption

   The gas consumption was above that listed in the ICD-SLD-47-000001-801, but not in excess of the reserve available within the supply. NASA must consider the impact of this on extended pre-launch waits. See CARR RID M-1.

4. Weight

   The LFC weight came in 45.8 pounds (or 5%) heavy. This was accepted.

5. Best Focus

   Through focus testing indicates the LFC may be .001" or .0015" away from best focus. Test data was gathered using a defocussed autocollimator. Since NASA may want to fly the LFC on an RB57, which necessitates a focal plane shift, no change was made at this time. NASA will eventually adjust for best focus (this adjustment is a normal LFC operational feature). See CARR RID 02.

6. GPCA Problems

   The GPCA pressure transducers did not work per spec. in vacuum. This was realized prior to test and an agreement to replace them and retest the GPCA at the vendor after the ATV test was made. Following acceptance of the LFC, the GPCA was returned to Carleton for rework, retest and eventual shipment to NASA Houston.

SECTION 13 - BIBLIOGRAPHY

Test Procedures
PDR Documents
CDR Documents
ADP Documents
ICD's
CEI Specs
Top Level Drawings
Family Trees
Plans
Reports
Related Documents
Contractual Documents
Failure Reports

TEST PROCEDURES

ES225363	Test Plan for Large Format Camera Cartographic Lens
TP225038	Magazine Assembly
TP225055	IRIG Input PWB
TP225060	Frame and Mission PWB
TP225065	Main Storage PWB
TP225070	28V Interface PWB
TP225075	T/M Interface "A" PWB
TP225080	T/M Interface "B" PWB
TP225090	T/M Interface "C" PWB
TP225095	T/M Interface "D" PWB
TP225100	T/M Interface "E" PWB
TP225110	Bit/Flag Generator #1
TP225115	Math Unit
TP225120	S. T. and C. "A" PWB
TP225125	S. T. and C. "B" PWB
TP225138	Capping and Rotary Shutter Assembly
TP225145	Supply Servo, Pre-Amp
TP225150	Takeup Servo, Pre-Amp
TP225155	FMC Servo Preamp PWB
TP225160	Rotary Shutter PWB
TP225164	Exposure Sensor Calibration
TP225165	Capping Shutter Servo
TP225170	Filter Changer and Thermal Door PWB
TP225180	Printer Control PWB
TP225190	Filter Changer Assembly
TP225195	System Timing and Control "C"
TP225249	Reseau Calibration
TP225250	Framing Roller Servo PWB
TP225260	Reseau PWB
TP225280	Lens Cone and Magazine Support Electronics PWB's (A42)
TP225280	Lens Cone and Magazine Support Electronics PWB's (A53)
TP225290	Bit/Flag Generator #2
TP225294	Thermal Door Assembly
TP225550	Auxiliary Data Decode PWB
TP225669	LFC Integration
TP225670	Large Format Camera Functional Test
TP225671	System Temperature Control Test
TP225672	LFC System EMI/EMC Acceptance Test
TP225673	Vibration
TP225674	System Short Form Functional (Pre-Vibration, Post-Vibration)
TP225675	Thermal Vacuum
TP225676	System Mass Properties
TP225677	LFC Pre-Installation
TP225686	System Data Presentation Test
TP225688	FMC Performance
TP225765	Frame Count T/M PWB
TP225770	Film Change Detector PWB
TP225795	Exposure Sensor Sample PWB
TP225858	T & C Console Acceptance Test

PDR DOCUMENTATION

9555-78-169, 318 (ITEK) - PDR Minutes (Abbreviated)
JSC-14656 (NASA) - PDR Minutes (Detailed)
9555-79-445 (ITEK) - Closure of Open RID's

CDR DOCUMENTATION

9555-78-240	-		- CDR Doc. Pkg.
9555-79-428	-	DRL Line #27	- Agenda
9555-79-381	-	DRL Line #2	- EEE & Non-Metallics List
9555-79-351	-	DRL Line #3	- Limited Life List
9555-79-387	-	DRL Line #21	- Baseline Documentation
9555-78-007A	-	DRL Line #8	- Acceptance Test Plan
9555-79-483	-	DRL Line #26	- CEI Specification
9555-79-420	-	DRL Line #23	- Engineering Dwg's.
9555-80-928	-		- CDR Briefing Book
9555-79-428	-	DRL Line #28	- Minutes
9555-79-434	-		- Closure of Open RID's
9555-79-415, 438	-		- Technical Direction at CDR
9555-79-371	-		- Carleton GPCA Design Review

CARR DOCUMENTATION

JSC CARR Minutes

ADP ITEMS (ACCEPTANCE DATA PACKAGE)
DRL LINE #20

Book I

Component/Equipment Historical Log
Engineering Drawings
Inventory of Installed Serialized Components
Waiver/Deviations
Discrepancy Reports/Material Review Board Actions/Failure Reports
Operating, Maintenance, and Handling Procedures (Manual: DRL Line #31)
Record of Limited Life/Time and Cycle Requirements
Nonflight or Temporary Installed Hardware
Test Procedures and Results ES225363 and TP225038 to TP225095

Book II

Test Procedures and Results: TP225100 to TP225672

Book III

Test Procedures and Results: TP225673 to TP225858

Book IV

Weights Log and Center of Gravity Data
Certification of Compliance
Certification of Acceptance
Open Work
CEI Specifications
Schematics
Indentured Parts List
Calibration Data Report

ADP ITEMS CONT.

Additional Volumes

Certification Analysis
ATV Test No. 2 (10/26/80)
Log Book: Film Magazine S/N 001
Log Book: Lens Cone S/N 001
Log Book: Camera Electronics S/N 001
Log Book: Large Format Camera S/N 001
Acceptance Data Package, Gas Supply Assy.
Test Report, Cartographic Lens Assembly
AWAR Results
DBTU Resolution Test Films
DBTU Distortion Test Films
Reseau Calibration Test Plate
Principal Point of Autocollimation Test Films
ATV #2 Test Films & Chart Recorder Traces

INTERFACE CONTROL DOCUMENTS

NASA ICD-2-19001	Shuttle System/Cargo Standard Interface Specification
ESA Ref No. SLP 2104	- ESA Spacelab Payload Accommodation Handbook
SLD-47-000001-801	- Functional (OCPS)
SLD-47-000001-802	- Mechanical (OCPS)
SLD-47-000001-803	- Electrical (OCPS)
SLD-47-000001-804	- Environmental (OCPS)
SLD-47-000001-808	- Gas Supply Assembly (OCPS)
SLD-47-000001-901	- BTE & Ground Handling Equipment (OCPS)
SLD-47-000001-902	- Launch and Recovery Facilities (OCPS)

CONTRACT END ITEM (CEI) SPECIFICATIONS
(DRL Line #26)

CEI 225000	- DRL #T-1418, Line Item 26 Large Format Camera
CEI 225905	- DRL #T-1418, Line Item 26 GSE for the LFC

TOP LEVEL ENGINEERING DRAWINGS

LFC: 225000: Large Format Camera
9555-80-930: LFC Configuration Identification and Accounting Index (P/O DRL Line #23 & 24)
Lens Cone Assembly 225130
Film Magazine Assembly 225038
Electronics Assembly 225085
Environmental Enclosure 225294
High Pressure Gas Supply Assembly 225206
Film Spools (4000') 225140

GSE: T&C Console 225858
T&C Cables 225829
Camera Cables 225883
Extender Card 225592
Lifting Fixture 198623
Spool Handling Sling 198634
Film Magazine Dolly 225800
Lens Cone Dolly 198650
Lens Cone Cover, Front 225802
Lens Cone Cover, Rear 225827
Film Magazine Cover 225853
Film Thickness Adjustment Fixture 225812
Focal Plane Calibration Fixture 225808
Shipping Container, Lens Cone 225899
Shipping Container, Film Magazine 225899

FAMILY TREES

225003 - OCPS Flight System
225021 - Cartographic Lens Assembly
225022 - Lens Cone Assembly
225023 - Film Magazine Assembly
225024 - Camera Electronics Assembly
225865 - T&C Console Assembly

PLANS

9555-78-007A - DRL Line #8 - "Acceptance Test Plan"
9555-78-006A - DRL Line #7 - "Spares & Repair Parts Support Plan"
9555-78-011 - - "Plan for New Technology"
9555-78-005 - DRL Line #6 - "Configuration Management Plan"
9555-78-008 - DRL Line #9 - "Inspection System Plan"
9555-78-009 - DRL Line #10 - "S,R,Q & M Plan"
9555-78-004C - DRL Line #5 - "Management Plan"
9555-78-010A - DRL Line #18 - "Certification Plan"
9555-78-028 - DRL Line #4 - "Work Breakdown Structure"
9555-78-033 - DRL Line #22 - "Program Master Schedule"
9555-78-060 - DRL Line #29 - "EEE Parts Derating"
9555-78-054A - - "EEE Parts Selection Criterion"

MISC. REPORTS

9555-80-850 - DRL Line #2 - Nonmetallic Materials and EEE Parts List
9555-79-543 - - Lubrication Specification
9555-79-520 - - Operating Period
9555-79-358A - - FMEA
9555-79-674 - - Safety Matrix and Hazards List
9555-79-351 - DRL Line #3 - Limited Life Parts List
9555-80-929 - DRL Line #21 - CDR Baseline Documentation
9555-80-932 - DRL Line #17 - Final Acceptance Report

FMC Reports

9555-78-056 - FMC System Requirements
9555-78-063 - FMC/Rotary Shutter Parametric Analysis
9555-78-064 - FMC Error Analysis
9555-78-069 - FMC Accuracy and Control
9555-78-074 - FMC Drive
9555-79-301A - FMC Error Tolerance

Exposure Control Reports

9555-78-038 - Rotary Shutter Constraints
9555-78-062 - Rotary Shutter Parametric Analysis
9555-79-297 - Exposure Time and Shutter Efficiency
9555-79-296 - Exposure Time Requirements
9555-79-352 - Capping Shutter
9555-79-748 - Rotary Shutter Encoder Setup
9555-79-251 - Exposure Sensor Testing
9555-79-303 - Exposure Sensor Concept
9555-79-687 - Exposure Sensor Checker

Reports of a System Level Interest

9555-78-021 - Mission Analysis
9555-78-138 - LFC Life Requirements
9555-78-230 - Star Field Calibration
9555-79-335 - Metric Error Analysis
9555-79-471 - LFC Calibration at USGS
9555-79-487 - Flight Support Structure: Prelim. Analysis
9555-79-512 - White Paper for POCC
9555-79-604 - TDRSS Ground Stations and Satellite Geographical Locations
9555-79-613 - Vehicle Disturbances, Thrusters
9555-79-605, 629 - Command Generation, Data Handling

Platen Reports

9555-79-331 - Platen Breadboard Test Report
9555-79-333 - Magazine Base/Platen Deflections
9555-79-334 - Platen Surface Deflections
9555-79-463 - 180 Reseau Study
9555-79-524 - Temperature Effects of Increased Reseau
9555-79-550 - Increased Reseau Status
9555-79-743 - Increased Reseau Report

Framing Roller Reports

9555-78-058 - Framing Roller Requirements

Lens Reports

9555-78-055 - Evaluation and Calibration of the Aspheric Measuring Machine
9555-78-155, 300 - Defocus Sensitivity of the LFC

Lens Reports Cont.

9555-79-284 - Prototype Lens Qual. Testing
9555-79-285 - Trip Report: Lens Cone Casting
9555-79-298 - Static Tolerances for Lens
9555-79-299 - Predicted Lab Resolution
9555-79-302 - Thru Focus Test Requirements
9555-79-327 - Radial Distortion Correction
9555-79-330 - Distortion and Focus Sensitivity to Pressure
9555-79-488, 509 - Flatness of Glass Photo Plates
9555-79-489 - Lens Cell Stress Concentrations
9555-79-505 - Cal. Fixture Reseau Pattern
9555-79-541 - Film vs Glass Plates
9555-79-566 - Lens Cell Machining Meeting
9555-79-669 - Lens Cell Prints from Contraves
9555-79-683 - Lens Assembly Procedure
9555-79-685 - Lens Cell Spaces: Machining and Heat Treatment
9555-79-707, 708 - Quad Ring vs O-Ring for Lens Cell
9555-79-716 - 50 Durometer Silicone O-Rings
9555-79-770 - Lens Data Evaluation

Thermal Door/Filter Changer Reports

9555-78-059 - Thermal Door Requirements
9555-78-137, 146 - Globe Motor (Thermal Door & Filter Chg.)
9555-78-208 - Limit Switches (Thermal Door & Filter Chg.)

Thermal Reports

9555-78-119 - Thermal Paint (&)
9555-78-126 - Temperature Controller Reliability
9555-79-357 - Thermal Analysis
9555-79-746, 749 - Temperature Controller

Spooling System Reports

9555-78-076 - LFC RAMP UP/RAMP DOWN
9555-78-103 - Loading/Unloading of Spools
9555-79-348 - LFC Spooling
9555-80-860 - Film Tension
9555-79-539, 544 - Spooling Film on Core

MISC.

9555-78-084 - Reliability Critical Items List
9555-78-099 - LFC Maintainance Concept
9555-78-167 - Parts Quality Sensitivity Analysis
9555-79-304 - LFC Constructional Requirements
9555-79-332 - Structural Analysis Results (NASTRAN) for LFC
9555-79-355 - Mechanical Error Budget
9555-79-493 - Mount Stress Analysis
9555-79-494 - Magazine Clamping
9555-79-676 - MTBF Prediction

Misc. Cont.

9555-79-700 - List of Printed Wiring Boards without Test Version
9555-80-837 - Inland Servo Power Amplifiers
9555-80-900 - Failure Report & DMR Summary

RELATED DOCUMENTS

Proposal

"Efficient Computer Conversion of Digital Terrain Data: LFC/GPM Photogrammetric System" Ref. NASA, AN: OSTA-79-A Section 1, Para. 3(b) (1). NASA Control Number 044-NR-23.

"Digital Terrain Data Accuracy Investigation: LFC/GPM Photogrammetry System" Ref. NASA, AN: OSTA-79-A Section 1, Para. 3 (b) (1). NASA Control Number 045-NR-24.

"Large Format Camera Attitude Reference Package" Itek 3141-79-001, 9555-79-755.

"Orbiter Camera Payload System" Vol. I Technical Proposal Itek 78-3113A-1. Vol IV Cost Proposal Itek 78-3113A-4. Vol. III Addendum to Tech. Prop. Itek 78-3113A-3. Vol. II Management Proposal Itek 78-3113A-2.

Study

9555-79-629 (July 3, 1979) "A Feasibility Study to Fulfill the Requirements of Mission Planning, Command Generation and Data Handling for the NASA Sponsored OCPS/EOCPS Systems".

9555-79-565 "Services and Data Required from POCC to Operate LFC During Flight".

351-79-022 (Project 5908.3, Itek) R&D Report: "Camera Components - High Density Reseau".

"Feasibility Study for the Application of the LFC as a Payload for the Orbiter Program". Contract NAS9-15490 Itek Report 78-9549A-2, Rev. A.

Brochure

Flyer: "LFC: Large Format Camera" Itek SPG80-047

Papers

"Environmental Factors in the Design of the Large Format Camera" by George A. Wood 14th Congress of the International Society of Photogrammetry, Hamburg 1980.

"The Orbiter Camera Payload System and the Large Format Camera" by B. Mollberg, 14th Congress of the International Society of Photogrammetry, Hamburg 1980.

"Orbiter Camera Payload System" B. Mollberg Society of Photo-Optical Instrumentation Engineers, May 24, 1979.

Papers Cont.

"Earth Orbital Photography by the Large Format Camera" by Farouk El-Baz, Smithsonian Institution and R. J. Ondrejka, Itek, 12th International Symposium on Remote Sensing of Environment, Manila, 1978

"Fotografia Orbital Terrestic Con La Camera Cartoespacial" by R. J. Ondrejka, Semana DeIntercambio Technologico Panama, 1979 and Brazilian Society of Photogrammetry Cruitiba, 1979

"A Large Format Camera for Shuttle" by Frederick J. Doyle, American Society of Photogrammetry, March 1978.

"The Large Format Camera for Space Shuttle" Frederick J. Doyle, 14th Congress of the International Society of Photogrammetry, Hamburg 1980.

"Earth Orbiting Camera Systems" by G. Konecory, 14th Congress of the International Society of Photogrammetry, Hamburg 1980.

Hearings before the United States Senate on the Civil Remote Sensing Satellite System, June 26 and July 24, 1980: Serial No. 96-111, US GPO, Pages 129 to 142

Papers Cont.

"Mission Planning Parameters for the Space Shuttle Large Format Camera" by George A. Wood ASP Convention March 1979.

Article

"Shuttle Era Space Photography" by George A. Wood and Ron Ondrejka Optical Spectra December 1980.

CONTRACTUAL DOCUMENTS

Contract NAS9-15671 7/21/78

Attachment I - Reports and Data Duplication
Attachment II - General Provisions
Exhibit A - Statement of Work
Exhibit B - Technical Specification

Contract Change Items

TYPE	NUMBER	DATED	
DCN	63301	3/2/79	Update Tech. Spec. to CDR Baseline
DCN	63302	4/6/79	Implements PDR RID E2
CCA	1	12/4/78	Implement PDR RID's E5, E7, SY5
CCA	2	3/29/79	Implement Various RIDS, etc.
CCA	2 Am 1	8/10/79	Complete Flight Support Structure Design Only
CCA	2 Am 2	8/31/79	Complete Flight Support Structure Design Only
CCA	2 Am 3		Delete Flight Support Structure
CCA	3	4/19/79	Predict Cloud Cover
CCA	3 Am 1	5/24/79	Cease Work under CCA3
CCA	4	5/3/79	Change Flight Cables to Test Cables
CCA	5	7/31/79	Add a High Pressure Gas Supply
CCA	6	12/31/79	Delete Personal Radiation Dosimeter
MOD	1S	10/23/78	Funding Increase
MOD	2S	12/12/78	GFP Change, Use of Govt. Property
MOD	3S	2/5/79	Funding Increase
MOD	4S	3/9/79	Costing Change; add FCD; Study Commands
MOD	5S	4/16/79	Funding Increase
MOD	6S	7/24/79	Funding Increase
MOD	7S		Costing Change; GFP List, Change of End Date of Contract, Study Exp. Sensor
MOD	8S		Funding Increase
MOD	9S		Costing Change; GSA Rates
MOD	10S		Funding Increase
MOD	11S		Funding Increase; Financial Reporting
MOD	12S	12/31/79	Funding Increase
MOD	13S	1/7/80	Funding Increase
MOD	14S	2/13/80	Funding Increase
MOD	15C	4/11/80	Funding Increase
MOD	16S	6/5/80	
MOD	17C	7/18/80	
MOD	18S	8/26/80	
MOD	19C	8/26/80	
MOD	20S	11/3/80	
MOD	21		TBD

TYPE	NUMBER	DATED	
ECP	1	8/31/79	9555-79-714: Thermal Paint
CCP	1	12/15/78	FCD Study
CCP	2	12/15/78	Digital Command Study
CCP	3	3/29/79	FCD
CCP	4	4/11/79	V/h Command Change
CCP	5	4/11/79	Analog TM Frame Count
CCP	6	4/9/79	Center Exposure Pulse Change
CCP	7	4/26/79	Reseau Study
CCP	8	5/3/79	Personal Radiation Dosimeter Impact
CCP	9	5/10/79	Exposure Sensor Changes
CCP	10	5/10/79	Cloud Study - Cancelled
CCP	11	5/23/79	GSA
CCP	12	6/4/79	Low Profile Cover
CCP	13	7/27/79	Field Support
CCP	14	9/24/79	Mission Planning, Commands & Data
CCP	15	11/15/79	New Reseau Plate
CCP	16	11/30/79	Deletion of Flight Support Structure

SECTION 14 - APPENDICES

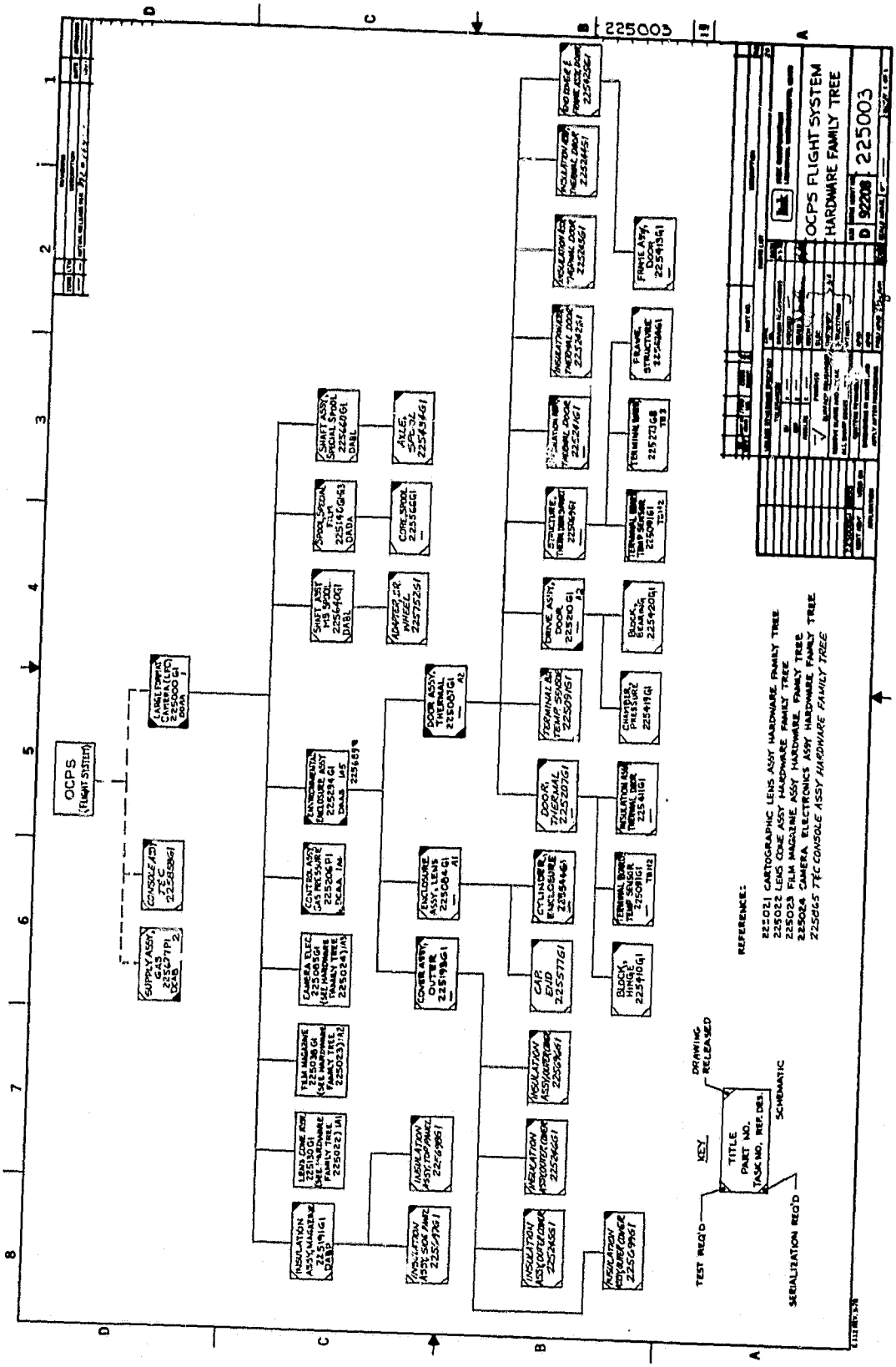
A. FAMILY TREES

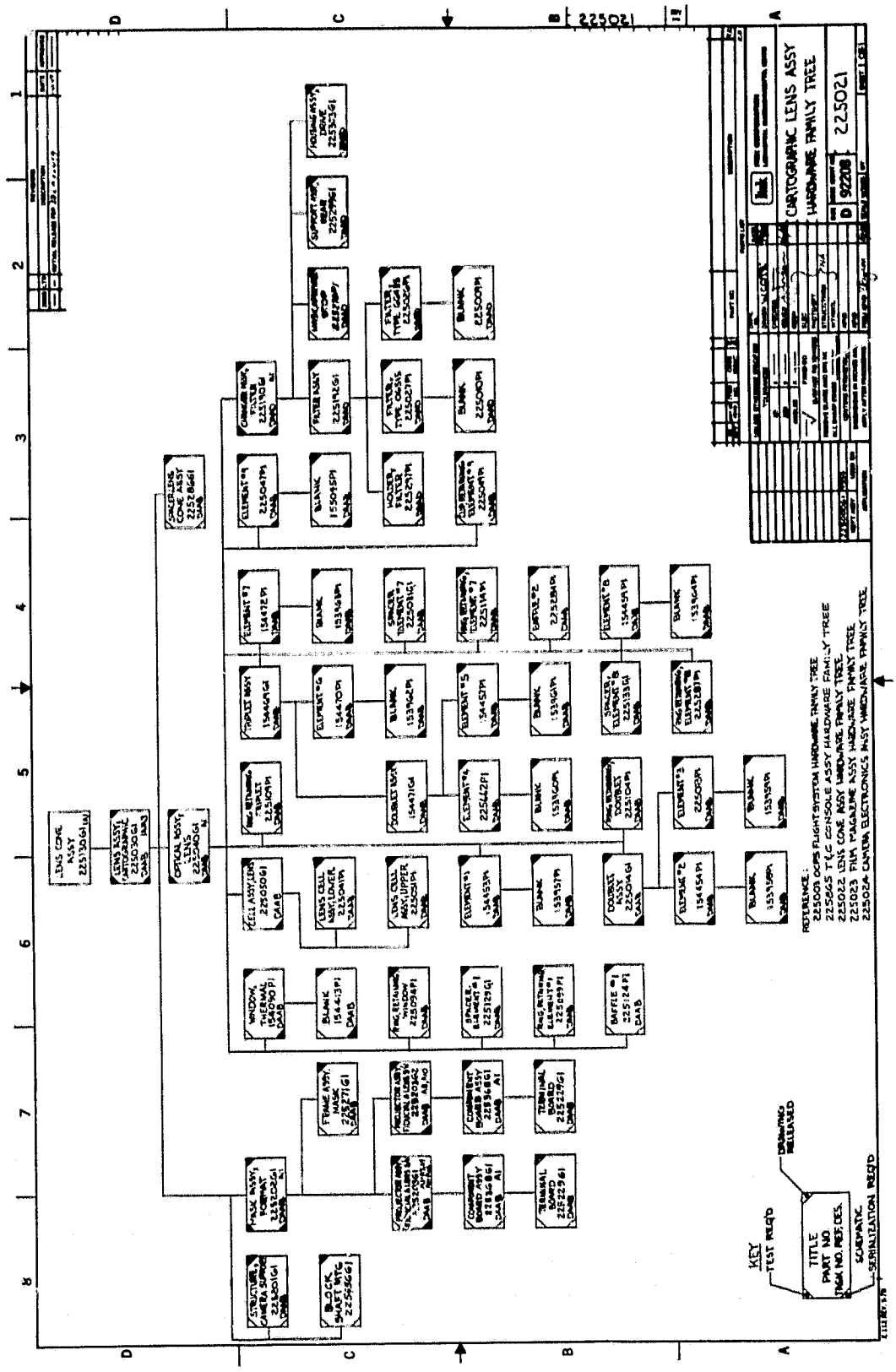
B. FAILURE REPORT SUMMARY

C. SIGNED OFF DD250 FORMS

D. PROGRAM MASTER SCHEDULE

APPENDIX A - FAMILY TREES





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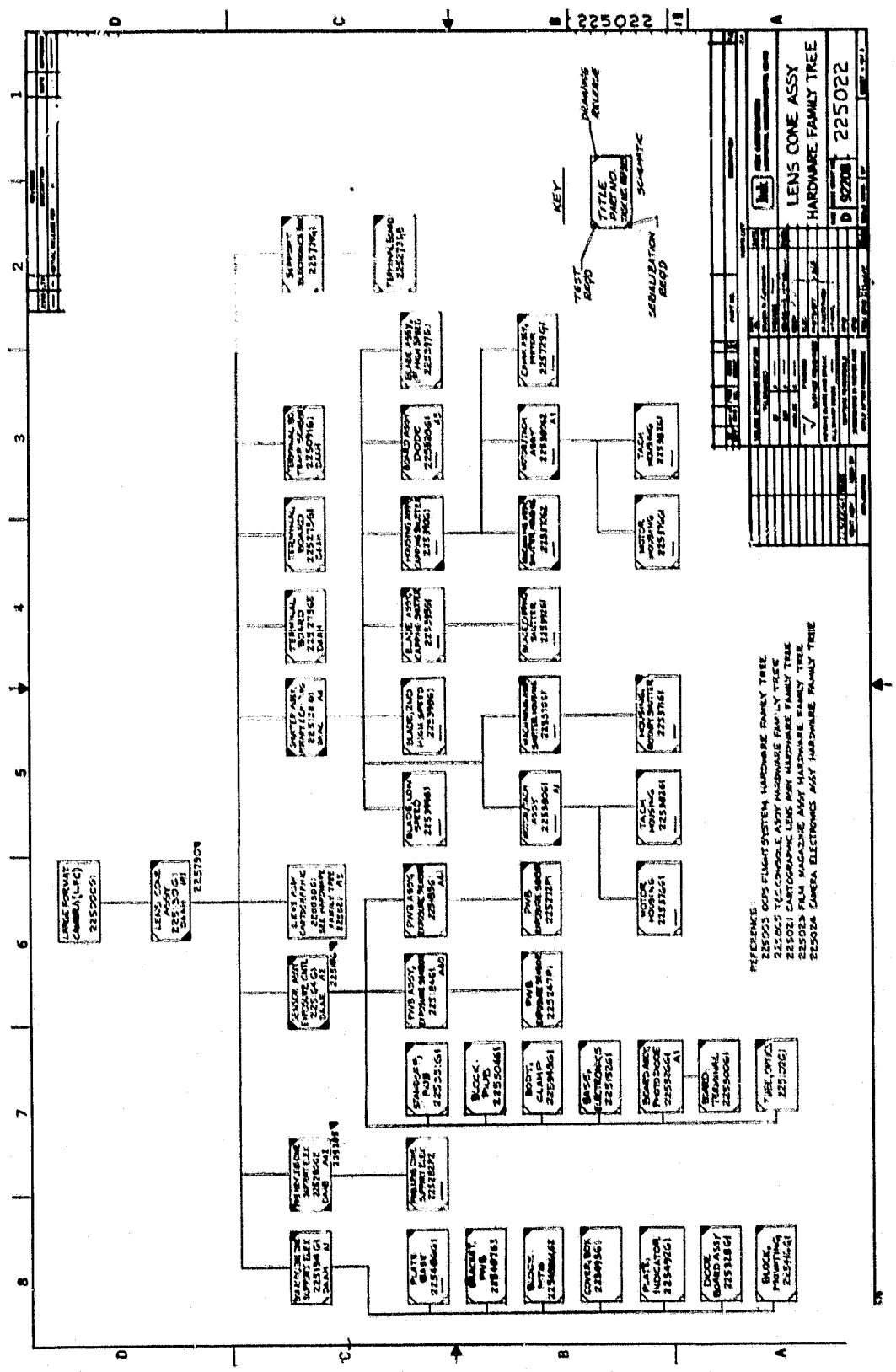

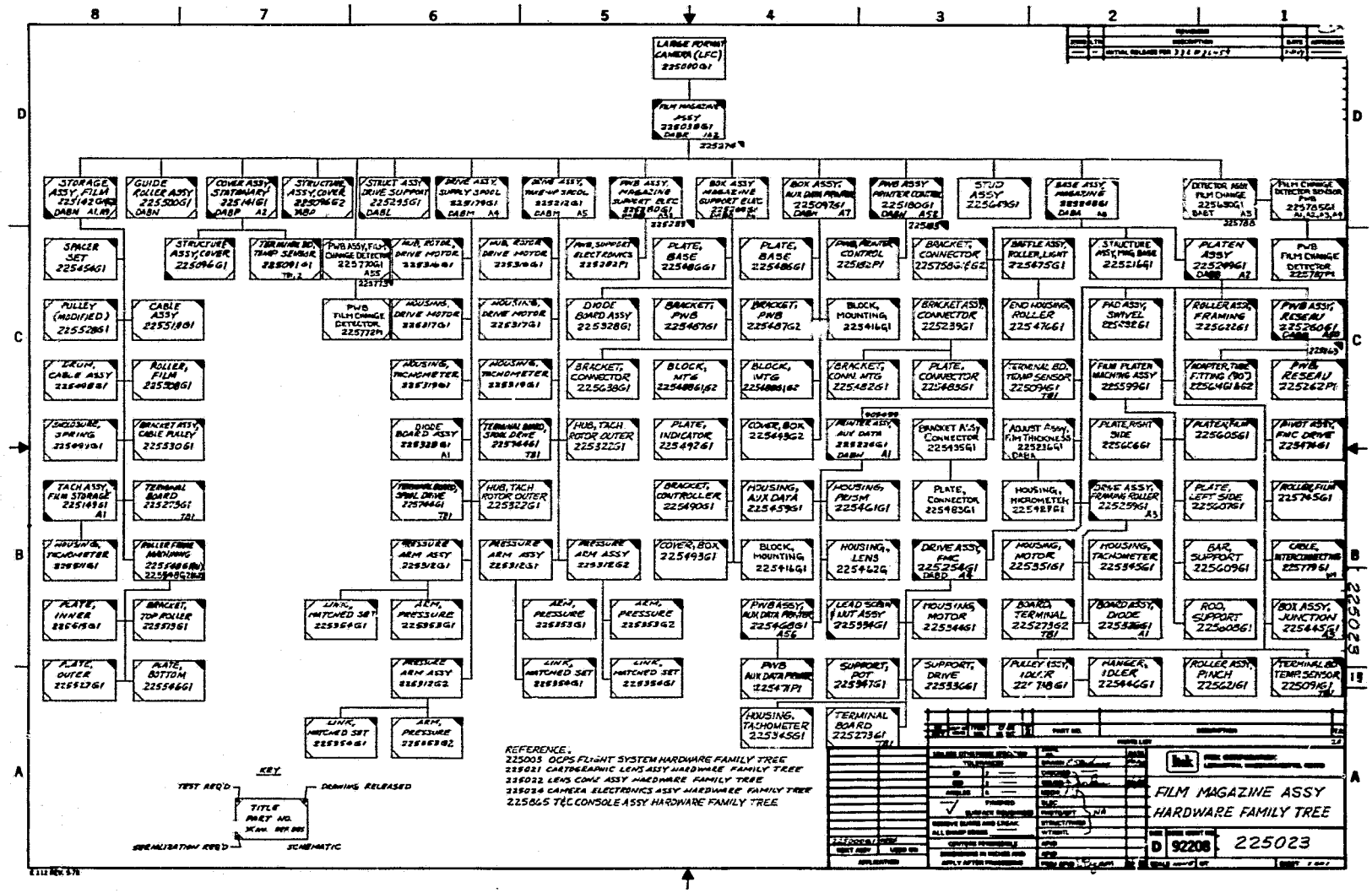

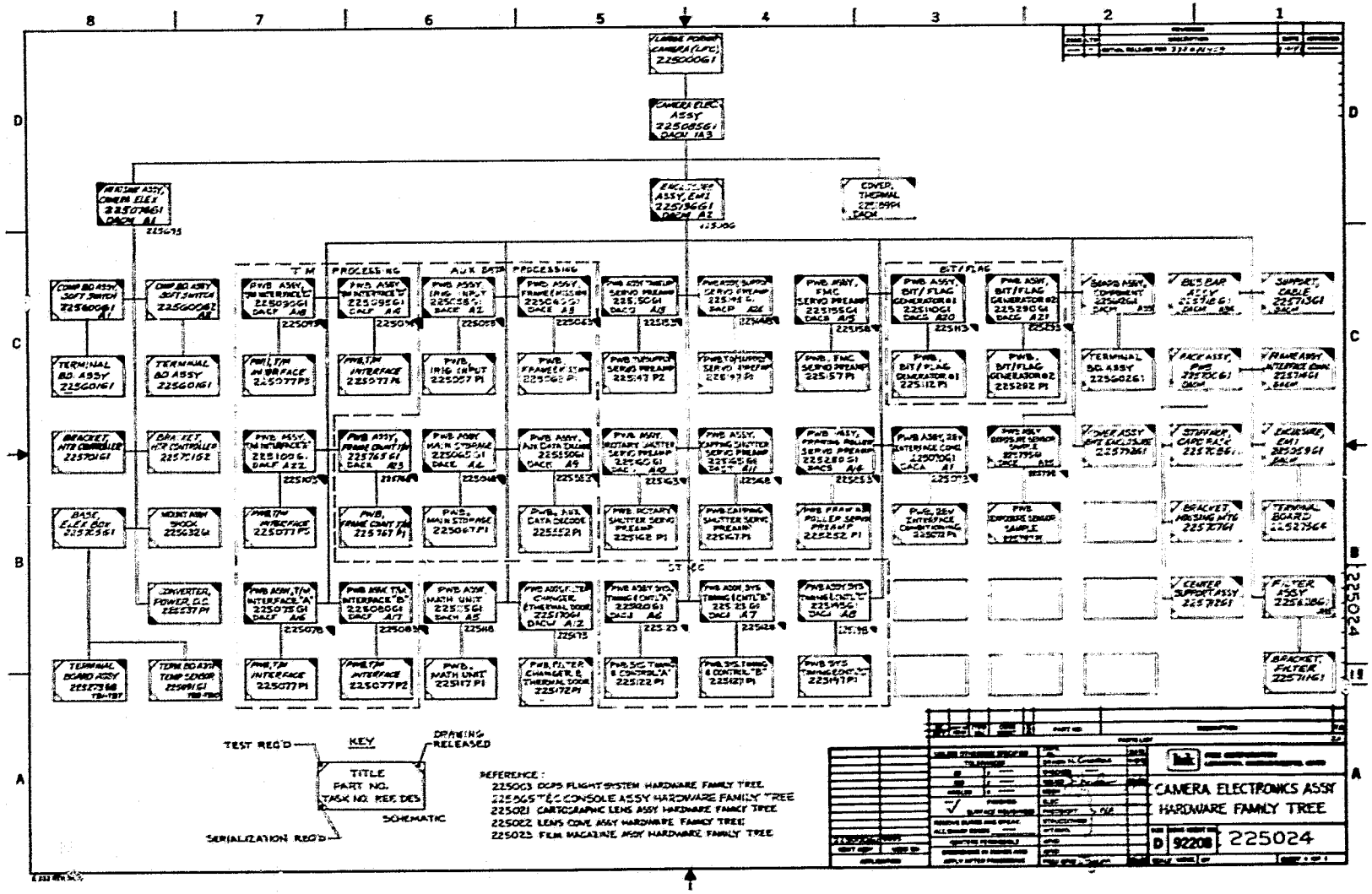

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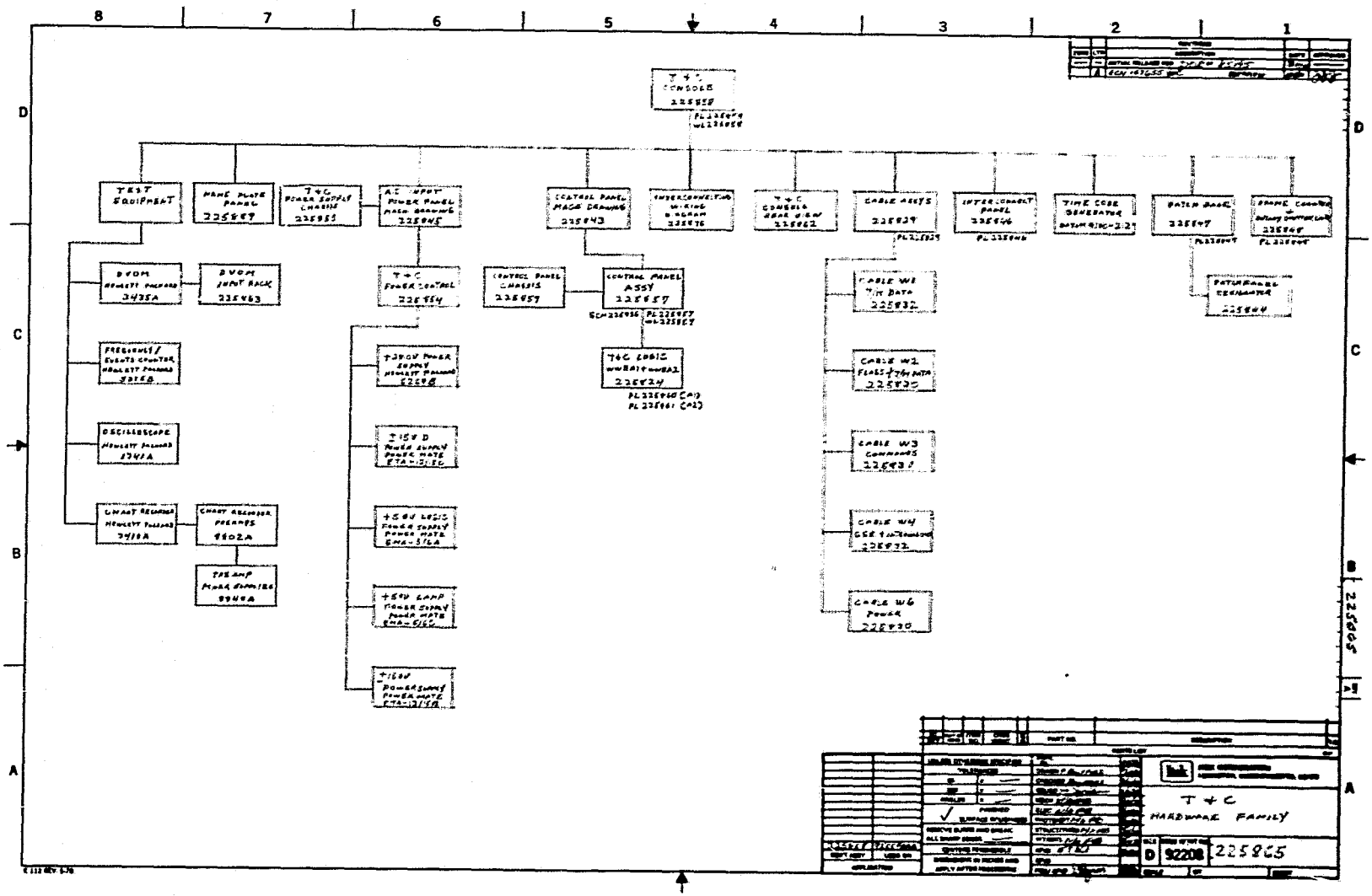

APPENDIX B - SUMMARY OF FAILURE REPORTS

SUMMARY OF FAILURE REPORTS AND RELATED DMR's

FR #	DMR #	DATE	FAILURE/DISCREPANCY	DISPOSITION	VERIFICATION
3696	42162	5/15/80	Window Separated from Environmental Enclosure	Reassembled using Catalyst	Examination and Physical Test
3697	42164	6/3/80	Gas Pressure Control Assembly (GPCA) does not function in vacuum	Carleton Report 80-52	
3698	47377	6/18/80	No readout from thermal door TM Sensor. Analysis suggests exposure to 100V	Replaced Sensor system voltage limit is 34V	Ckt Analysis Testing to Date
2828	47378	6/30/80	Film Transport Signals indicated abnormal framing	Re-design per ECN148956 (A9 C2)	Ckt. Analysis Testing to Date
3697	47379	7/1/80	1. Go lamp out 2. High Voltage Reading	1. Related to FR3697 2. TP Revision will correct over-heating	
2828	47380	7/8/80	1. Failed to start on command 2. Stopped without command 3. Abnormal Supply & T.U. Signals	Re-design per ECN148956 (A9 C2)	Ckt. Analysis Testing to Date
3697	47381	7/8/80	TP PARA. ATV TEST 225675		
			a. 4.12 Pressure = 30 S/B 20	See FR 3697	
			b. 4.13 Commercial Regulator	See FR 3697	
			c. 5.3 Tested @ 28V S/B 32V		
			d. 5.8 Not done (Therm. Dr. Override		
			e. 7.2, 7.3 GPCA not used	See FR 3697	
			f. 7.7 No fogging fixture		
			g. 8.0 Omitted (Gas Leak Test)	See FR 3697	
3699	47383	7/7/80	Standby Mode does not disconnect 28V power to supply and take-up motors	Replace Q1, Q4, K1 Remove Burrs to eliminate short ckt.	Ckt Analysis Testing to Date
2826	47385	7/8/80	1. Resolution low due to poor focus 2. FMC deviation = 14% S/B within 10%	1. Platen reposition (McLellan Memo) 2. Re-set Platen speed for FMC	
2828	47384	7/5/80	1. Frame count on film did not advance	1. None. Problem could not be induced again	1. Single event may have been connector or test problem
			2. Auxiliary Data spacing erratic	2. Re-design per ECN148956 (A9 C2)	2. Ckt Analysis Testing to Date

APPENDIX C - DD250 FORMS

AND
RECEIVING REPORT

NAS9-15671

DATE

ACCEPTANCE POINT: Origin

1. SHIPMENT NO.	2. DATE SHIPPED	4. B/L	5. DISCOUNT TERMS
TK 0001	5/5/80	TCN K4,696,770	N/A

12805

6. PRIME CONTRACTOR CODE 92208

tek Corporation
ptical Systems Division
0 Maguire Road
exington, MA 02173

7. ADMINISTERED BY CODE

NASA
L. B. Johnson Space Center
Shuttle Payload Proc. Section/BC24
Houston, TX 77058

8. SHIPPED FROM (If other than 6) CODE FOB: Origin

Same as Above

10. PAYMENT WILL BE MADE BY CODE

Same as Above

9. SHIPPED TO CODE

ransportation Officer, Building 420
ASA
. B. Johnson Space Center
ouston, TX 77058

11. MARKED FOR CODE

Accountable Property Officer 807407
For Reissue to:
B. H. Mollberg/ED82, Bldg. 15, Room 214

A. ITEM NO.	16. STOCK/PART NO. DESCRIPTION (Indicate number of shipping containers-type of container-container number.)	17. QUANTITY SHIP/REC'D *	18. UNIT	19. UNIT PRICE	20. AMOUNT
	225568P1 Rev. A, Flange, Spool	2			
	225566G1 Rev. B, Core, Spool	1			
	225567P1 Rev. A, Flange, Spool	2			
	MS51959-45 Screw, Flathead	15			
	These parts assembled constitute one film spool			$1,000	$1,000

PROCUREMENT QUALITY ASSURANCE

A. ORIGIN

[X] PCA [X] ACCEPTANCE of listed items has been made by me or under my supervision and they conform to contract, except as noted herein or on supporting documents.

80 MAY 16 — John N Wright
DATE — SIGNATURE OF AUTH GOVT REP

YPED NAME ND OFFICE — John N Wright 5220A

B. DESTINATION

[ ] PCA [ ] ACCEPTANCE of listed items has been made by me or under my supervision and they conform to contract, except as noted herein or on supporting documents.

DATE — SIGNATURE OF AUTH GOVT REP

TYPED NAME AND TITLE

22. RECEIVER'S USE

Quantities shown in column 17 were received in apparent good condition except as noted.

5/22/80 — Harry Mollberg
DATE RECEIVED — SIGNATURE OF AUTH GOVT REP

TYPED NAME AND OFFICE

* If quantity received by the Government is the same as quantity shipped, indicate by ✓. If quantity received differs, enter actual quantity received below quantity shipped and explain.

23. CONTRACTOR USE ONLY

Rec'd from Bach
6/18/80

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D FORM 250 1 NOV 68 REPLACES EDITION OF 1 AUG 67 WHICH MAY BE USED

"TO BE STORED IN A COOL DRY LOCATION"

MATERIAL INSPECTION AND RECEIVING REPORT

1. PROC. INSTRUMENT IDEN(CONTRACT) (ORDER) NO.	6. INVOICE NO. / DATE	7. PAGE 1 OF 2
NAS9-15671		8. ACCEPTANCE POINT S

2. SHIPMENT NO.	3. DATE SHIPPED	4. B/L	5. DISCOUNT TERMS
ITK 0002 Z	80DEC15E	TCN	N/A

9. PRIME CONTRACTOR CODE 92208	10. ADMINISTERED BY CODE A 83
Itek Corporation Optical Systems Division 10 Maguire Road Lexington, MA 02173	NASA L. B. Johnson Space Center Shuttle Payload Proc. Section/BC24 Houston, TX 77058
11. SHIPPED FROM (If other than 9) CODE / FOB: Origin	**12. PAYMENT WILL BE MADE BY CODE**
Same as Above	Same as Above
13. SHIPPED TO CODE	**14. MARKED FOR CODE**
Transportation Officer, Building 420 NASA L. B. Johnson Space Center Houston, TX 77058	Accountable Property Officer 807407 For Reissue to: B. H. Mollberg/ED82, Bldg. 15, Room 214 NAS 9-15671

15. ITEM NO.	16. STOCK/PART NO. DESCRIPTION (Indicate number of shipping containers - type of container - container number.)	17. QUANTITY SHP/REC'D *	18. UNIT	19. UNIT PRICE	20. AMOUNT
1.2 (a)	Flight Orbiter Camera Payload System: (Large Format Camera)				
1	Lens Cone Assembly (225130G1)	1			
2	Film Magazine Assembly (225038G1)	1			
3	Electronics Assembly (225085G1)	1			
4	Environmental Enclosure (225294G1)	1			
5	High Pressure Gas Supply System(225627P1)	1			
6	Film Spools (4000 ft.) (225140G1) (225140G2)	19			
1.2(b)	Ground Support and Checkout Equipment:				
1	Electrical Test & Checkout Unit (225858G1)	1			
2	TGC Cable Set (225829G1 thru G5)	1			
3	Extender Card Set (225592G1)	1			

21. PROCUREMENT QUALITY ASSURANCE

A. ORIGIN

☐ PQA ☒ ACCEPTANCE of listed items has been made by me or under my supervision and they conform to contract, except as noted herein or on supporting documents.

20 NOV 1980 — B. Hmollberg — NASA/JSC
DATE — SIGNATURE OF AUTH GOVT REP
TYPED NAME AND OFFICE: ED8/B. H. MOLLBERG

B. DESTINATION

☐ PQA ☐ ACCEPTANCE of listed items has been made by me or under my supervision and they conform to contract, except as noted herein or on supporting documents.

DATE — SIGNATURE OF AUTH GOVT REP
TYPED NAME AND TITLE

22. RECEIVER'S USE

Quantities shown in column 17 were received in apparent good condition except as noted.

DATE RECEIVED — SIGNATURE OF AUTH GOVT REP
TYPED NAME AND OFFICE

* If quantity received by the Government is the same as quantity shipped, indicate by (✓) mark, if different, enter actual quantity received below quantity shipped and encircle.

23. CONTRACTOR USE ONLY

MFG. 7-67

CAUTION -- REMOVE PROTECTIVE SHEET BEFORE TYPING
"TO BE STORED IN A COOL DRY LOCATION"

MATERIAL INSPECTION AND RECEIVING REPORT – *CONTINUATION SHEET*

PAGE 2 OF 2

SHIPMENT NO	DATE SHIPPED	PROC INSTRUMENT IDEN (CONTRACT)	ORDER NO	INVOICE NO
ITK 0002 Z		NAS9-15671		

ITEM NO.	STOCK/PART NO / DESCRIPTION (Indicate number of shipping containers - type of container - container number.)	QUANTITY SHIP/REC'D	UNIT	UNIT PRICE	AMOUNT
1.2(b)	(cont'd)				
4	Lifting Fixture Set (198623G1)	1			
5	Lens Cone Shipping Container (225899G1)	1			
6	Film Magazine Shipping Container (225899G2)	1			
7	Lens Cone Cover, Front (225802G1)	1			
8	Lens Cone Cover, Rear (225827G1)	1			
9	Film Magazine Cover (225853G1)	1			
10	Film Magazine Assy. Dolly (225800G1)	1			
11	Lens Cone Assy. Dolly (198650G1)	1			
12	Film Thickness Adjustment Plate (225812G1)	1			
13	Focal Plane Calibration Fixtuee (225808G1,2,3)	1			
14	Interconnecting Cabling (225883G1 thru G5)	1			
15	Spool Handling Sling (198634G1)	1			

APPENDIX D - PROGRAM MASTER SCHEDULE

PROJECT NO. 9555
TASK DESCRIPTION LARGE FORMAT CAMERA (LFC)
PROGRAM MASTER SCHEDULE

PROJECT SCHEDULE

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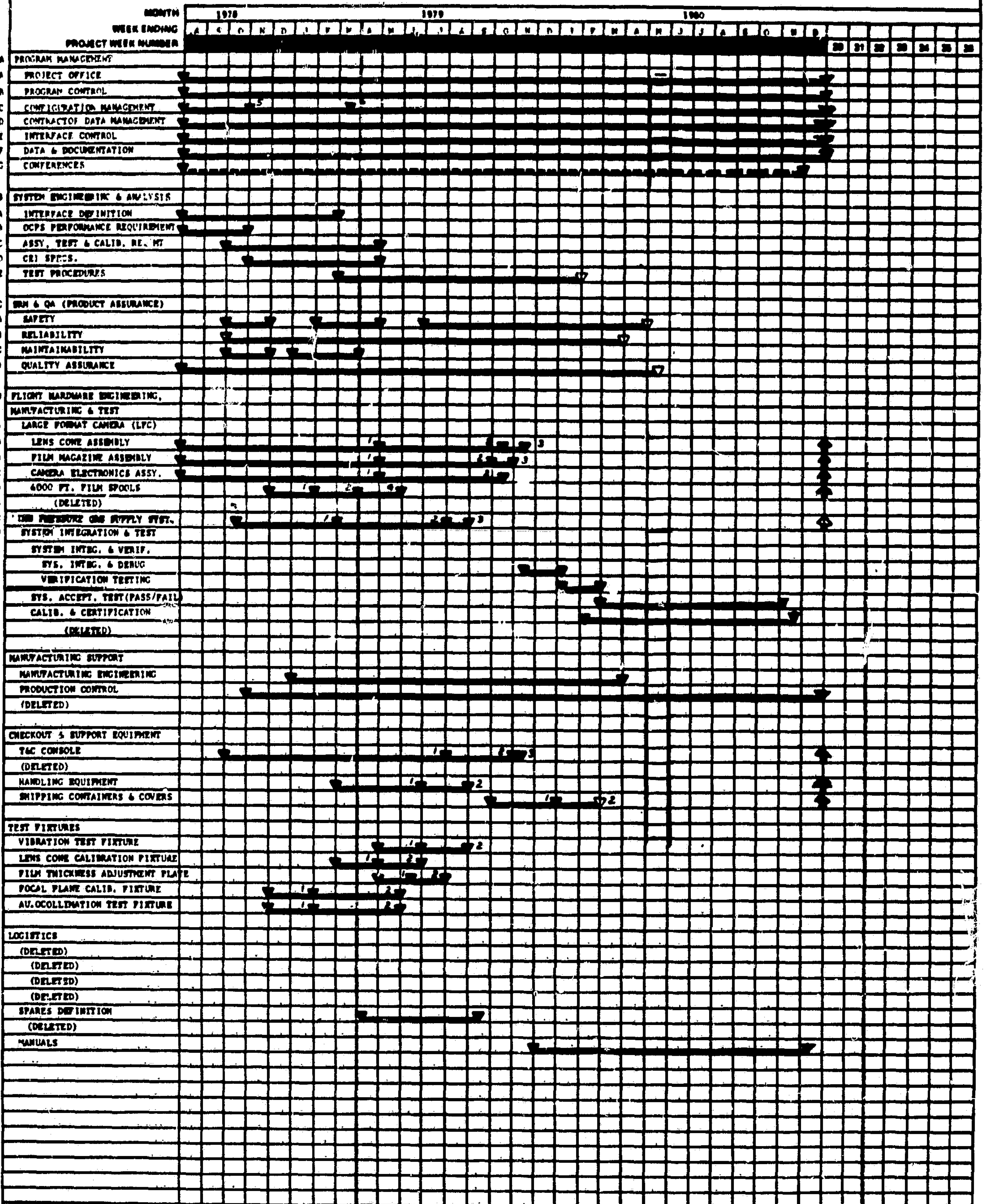
SHEET 1 OF 1



PREPARED BY: J. P. Massino DATE: 8/11/78
APPROVAL: R. R. Heath DATE 8/11/78
REVISED 11/16/78
REVISED 5/11/79

MILESTONES
1 ▽ COMPLETE DESIGN
2 ▽ COMPLETE MFG.
3 ▽ COMPLETE TEST
4 ▽ COMPLETE FILM LOADING
5 ▽ PDR
6 ▽ CDR
⇧ DELIVERABLE END ITEM